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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 123.
B. T. GALLOWAY, *Chief of Bureau.*

THE DECAY OF ORANGES WHILE IN TRANSIT FROM CALIFORNIA.

BY

G. HAROLD POWELL,
POMOLOGIST IN CHARGE OF FRUIT TRANSPORTATION AND STORAGE INVESTIGATIONS,

ASSISTED BY

A. V. STUBENRAUCH, L. S. TENNY, H. J. EUSTACE, G. W. HOSFORD, AND H. M. WHITE, OF FIELD INVESTIGATIONS IN POMOLOGY.

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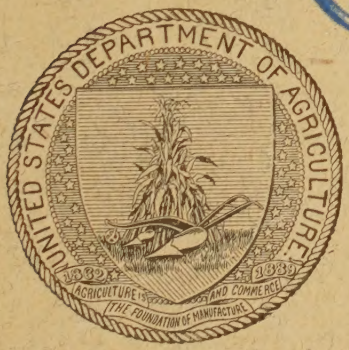

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WASHINGTON NAVEL ORANGES SHOWING BLUE-MOLD DECAY.

(Specimens considerably reduced in size)

BREUNER & KESSLER CO. PHILADA

U. S. DEPARTMENT OF AGRICULTURE.

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B. T. GALLOWAY, *Chief of Bureau.*

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., November 22, 1907.

SIR: I have the honor to transmit herewith a manuscript entitled "The Decay of Oranges While in Transit from California" and to recommend that it be published as Bulletin No. 123 of the Bureau series. It has been prepared by Mr. G. Harold Powell, Pomologist in Charge of Fruit Transportation and Storage Investigations, assisted by Messrs. A. V. Stubenrauch, L. S. Tenny, H. J. Eustace, G. W. Hosford, and H. M. White, all of Field Investigations in Pomology, and has been submitted by Mr. William A. Taylor, Pomologist in Charge of Field Investigations, with a view to publication.

The investigations summarized in this manuscript are unique in that they have involved the actual handling and careful inspection of large quantities of oranges through all the various operations to which the fruit is subjected in its progress from the trees in California to the markets in eastern cities. This has included the actual custody of numerous carload lots of fruit while in transit under different methods of railroad transportation. The investigations, in general, have been conducted on a commercial scale and under commercial conditions, with a view to securing accurate data regarding the practical requirements and needs of different phases of the industry, but the laboratory method has been applied to the fullest extent practicable under the conditions existing in the field, the packing house, the storage warehouse, the railroad car, and the salesroom.

The perishable character of the product under investigation, taken in connection with the physiological and economic factors involved in its harvesting, transportation, and sale, has apparently been responsible for much of the misapprehension that has hitherto existed regarding the causes of decay of California oranges in commerce. A satisfactory determination of those conditions has required continuous observation of large numbers of representative lots of fruits simultaneously at distant points. No individual producer or receiver has

found it practicable to make such an investigation. In fact, it developed early in the investigation that the problems could be promptly and economically solved only through the development of an organized corps of scientific workers who could prosecute different phases of the work simultaneously in the producing sections, in transit, and in some representative eastern market, maintaining continuous communication by mail and telegraph, so that the conditions to which the various shipments of fruit had been subjected could be thoroughly understood. Such a corps of workers has been gradually built up in this work, and the results set forth herein are believed to fully justify this feature of the Bureau organization.

The present paper is the first formal and comprehensive publication of the results of these investigations. It should be stated, however, that the various branches of the industry have been informed from time to time regarding the progress of the work. This has been accomplished through addresses delivered before meetings of growers and of various organizations of warehousemen, refrigerating engineers, and railroad men, as well as through the personal contact of a large number of packing-house foremen with the experimental work. Occasional circular letters summarizing the conclusions reached have been sent to the individuals and associations interested.

Largely as a result of the thorough organization of the industry and the active cooperative spirit shown by the leading men in it, a prompt and general modification of methods has resulted and is still in progress. While the work is not yet complete, it is believed that the phases reported upon should be given wider publicity in all our orange-producing districts because of the bearing they are likely to have upon the handling of this and other fruits in commerce.

The accompanying illustrations are necessary to a full understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE DECAY OF ORANGES WHILE IN TRANSIT FROM CALIFORNIA.

INTRODUCTION.

Soon after the United States Department of Agriculture, through the Bureau of Plant Industry, began a study of the storage and transportation of fruit the orange growers of southern California requested that an investigation be made of the decay in citrus fruits while in transit to eastern markets. The losses from decay were estimated variously to be from $500,000 to $1,500,000 annually.

The financial importance of this large amount of decay to the orange grower and shipper, to the buyer, and to the orange-consuming public made an investigation of the possible causes desirable.

A general survey of the industry was made in 1904, and for six months in each year since, experimental investigations have been carried on in an extensive way in the groves, in the packing houses, in the cars in transit to the East, and in the markets.

As this investigation has been so closely related to all the operations of the California citrus-fruit business, a general account of the industry will be necessary for a proper understanding of the discussion of the causes of decay in oranges during shipment.

GENERAL DESCRIPTION OF THE CALIFORNIA CITRUS-FRUIT INDUSTRY.

The introduction of the Washington Navel orange in 1870 from Bahia, Brazil, by the United States Department of Agriculture under the name of the "Bahia" orange and the sending of two trees propagated from those introduced from Brazil to Mrs. L. C. Tibbets, Riverside, Cal., in 1873, mark the most important epoch in the history of citrus-fruit culture in California. There were many types of oranges growing in southern California at that time, most of which were descended from trees planted in the gardens around the old missions by the Spanish fathers. None of these oranges equaled the new

Navel orange. This orange was a prolific bearer, the fruit of fine quality, the flesh meaty, juicy, and seedless, and the skin of a texture that insured good shipping quality, of a rich deep-orange color. The trees were of medium size, which made the groves more manageable than those of the tall-growing seedlings. This variety was named by the Californians the "Washington Navel," in honor of the city from which it was sent to them.[a] (Pl. I.)

The Washington Navel was widely planted in southern California, the State acquired a world-wide reputation for its citrus fruits, and a new era in orange culture in America began. In 1906–7 the Washington Navel crop in California reached a value of $12,500,000, with a gross value, including freight and icing charges, of $20,000,000.

The two trees sent to California by the Department of Agriculture are objects of historic interest in the city of Riverside at the present time. One of the trees was transplanted by the city from the Tibbets place in 1903 and stands in a thrifty condition at the head of Magnolia avenue. The other tree, shown in Plate II, figure 1, was transplanted in May, 1903, with the assistance of President Roosevelt, to the court of the Mission Inn.

THE EXTENT OF THE CITRUS-FRUIT INDUSTRY.

The citrus-fruit industry of California has grown up gradually. It began to assume commercial importance by 1880, and in 1886 amounted to a thousand carloads of 300 boxes each. Between 1890 and 1895 it had grown to from 4,000 to 7,000 carloads annually, and from 1900 to 1907 to between 25,000 and 32,000 carloads annually, i. e., from 6,000,000 to 11,000,000 boxes, having a gross value of about $1,000 a carload, or from $25,000,000 to $32,000,000.

The lemon comprises from 10 to 15 per cent of the citrus crop. There are a few pomelos (grape-fruit) grown. Three-fourths of the oranges are of the Washington Navel variety, the remainder comprising the Valencia as the most important variety, with fewer of the St. Michael, Mediterranean Sweet, Thompson, Ruby, Maltese Blood, Jaffa, seedlings, and tangerines. There are probably from 60,000 to 70,000 acres of citrus fruits in California, distributed among 5,000 to 6,000 growers. From 90 to 95 per cent of the citrus fruits are shipped to markets outside of California.

[a] The Washington Navel orange was first called "Bahia" by the late William Saunders, Horticulturist of the United States Department of Agriculture. This name has been adopted by the American Pomological Society and appears in its catalogue of fruits. The name "Washington Navel" is in almost universal use, however, and although of later origin than "Bahia" it will be used in this publication.

THE LOCATION OF THE CITRUS-FRUIT INDUSTRY.

The citrus-fruit industry has reached its greatest development in southern California, which is made up largely of the San Bernardino, San Gabriel, and San Fernando valleys. It has become most prominent in the foothill regions and lower lands extending down from the San Gabriel and San Bernardino mountains, which make up the Sierra Madre Range; in the Riverside district; at the base of the Temescal Range on the Corona bench, and in the Coast region in Orange and Los Angeles counties. There are smaller but not less favorable regions in Santa Barbara and Ventura counties, close to the mountains, and in San Diego County.

In recent years the industry has been developing north of the Tehachapi Range of the Sierra Madre Mountains, especially in Tulare, Kern, Fresno, and Butte counties, though oranges are grown to a limited extent in other fruit-growing counties in the central and northern parts of the State as well. The greatest development has occurred in Tulare County, where the annual production is now about 2,000 cars of oranges, mostly of the Washington Navel variety. New plantings have been made which under favorable conditions may increase the annual production in that section to 10,000 cars in the next few years.

The orange crop of northern California matures from four to six weeks earlier than it does in the southern part of the State, notwithstanding that it is from 200 to 500 miles farther north. This unusual condition is due to the topography of the Pacific coast. The large inland valleys of northern and central California lie between two great mountain ranges extending north and south. The Coast Range Mountains shut off the modifying influences of the sea, causing relatively higher night temperatures during the summer months than prevail in the southern part of the State.

CULTURAL CONDITIONS IN THE CITRUS-FRUIT BELT.

Citrus fruits are grown in California on many types of soil under an intensive system of orchard management. Irrigation is necessary except from December to April, when the rainfall usually occurs. As in other horticultural industries there has not yet been developed a uniform system of management in respect to the handling of the soil, the use of water, the application of fertilizers, or in the handling of the trees. In a general way, it may be said that the tillage is frequent and thorough during the season from March to August or September; that cover crops, especially winter vetch, Canada peas, and burr clover, are coming into general use as a winter covering and as a means of improving the condition of the soil; that pruning, except with the lemon, is not systematically practiced;

and that commercial fertilizers of various kinds are probably used more extensively than in any other orchard industry in the country, except in citrus-fruit growing in Florida.

The groves are variable in size, the smaller ones containing from 5 to 10 acres, the latter being a common unit of size. There are many of 15 to 20 acres or more, and the groves of some growers range from 100 to 200 or more acres. There are a few large companies and corporations engaged in the business, some of them having from 250 to 2,500 acres of citrus fruits.

A Washington Navel orange tree three years after planting is shown in Plate II, figure 2, and a typical view of orange groves in bearing is shown in Plate III, figure 1.

The harvesting of the Washington Navel crop begins in November in northern and central California, and extends to the middle of June or the first of July in southern California. The Valencia season opens the latter part of May and extends into the latter part of September or the first of October, the trees at that time bearing the crop to be harvested and the partly developed fruit for the crop of the following season. The other varieties of oranges are harvested from February to July. The lemon is picked from the same grove in practically every month of the year, although the largest part of the crop is harvested from November to May, a single tree generally containing fruit in all stages of development from the blossoms to the mature lemon.

METHODS OF HANDLING AND MARKETING THE CITRUS-FRUIT CROP.

The citrus-fruit growers of California are as a class men of high intelligence, and many of them are of large business experience and capacity. Cooperation in the handling of the citrus fruits is the corner stone on which many of the successful business practices rest. Among the various systems of marketing the fruit there have been developed some of the best examples of cooperative organization among fruit growers to be found in America.

These cooperative associations, organized primarily for the business of packing and distributing the fruit to market, handle from 70 to 75 per cent of the entire citrus-fruit crop.

There are also firms and individuals who pack, distribute, and sell fruit on commission for the growers. More or less of this fruit is sold f. o. b. cars in California, subject to inspection on arrival in market, or for cash f. o. b. cars in California, while some is consigned to distant merchants. There is also considerable buying of the fruit from the growers either by the pound or in lump in the orchard taken as a whole. There are a few growers and fruit-growing corporations who pack and market their own fruit. About 40 per cent of all citrus

fruits shipped from California is sold at public auction in eastern markets.

Among the cooperative organizations, the California Fruit Growers' Exchange packs and sells through its own district agents in the markets somewhat more than 50 per cent of the entire citrus crop. This organization is formed to regulate the distribution of citrus fruits throughout the country and to give to its members the benefits that arise from its cooperative efforts of various kinds. This Exchange represents about 4,000 growers, who are organized into more than 80 local incorporated associations, the primary function of which is to prepare the fruit for market. The associations in the different producing regions combine into one or more local incorporated district exchanges or selling agencies, which sell the fruit through the district agents or at public auction and receive the money therefor through the medium of the California Fruit Growers' Exchange. There are 13 of these district exchanges. Each local district exchange selects a representative to act for it on the board of directors of the California Fruit Growers' Exchange, which is an incorporated body acting as an agency or clearing house for the district exchanges in the marketing of their fruit and which operates for the growers without profit to itself. It takes the fruit of the district exchanges after it is packed, and with their cooperation and advice places it in the different markets of the country, sells it, collects the proceeds, and turns them over to the district exchanges, which in turn pay the growers through the local associations. The California Fruit Growers' Exchange is the agency through which the grower is able to control the larger business problems and the general policy of the handling and marketing of the citrus-fruit crop.

An association, whether a part of the California Fruit Growers' Exchange or organized independently, is composed of a number of growers who are incorporated with a board of directors and officers for business management. The association usually owns its own packing house, where the fruit of the members is assembled and prepared for shipment, or the association may lease a packing house from a railroad. The fruit of an association is marketed in the name of the association or of the district exchange of which the local association is a part, in the latter case both the name of the local association and the district exchange usually appearing on the package.

The fruit of the growers of an association may be handled as an individual account, but the usual method is to ship the different grades of fruit of all the growers under brands selected for each grade, the individual grower losing his identity so far as the market is concerned when the fruit enters the packing house and has been graded. In handling the fruit in this manner, the shipping season

is divided into periods varying from two to six weeks in length, and these periods are known as "pools." When a pool covers a month, it is referred to as a "January pool," "February pool," and so on. The members of the association are credited with the weight of each grade of fruit delivered, and at the end of a pool receive the pro rata of the proceeds represented by the quantity of fruit delivered to the packing house during that pool.

The responsibility of the association or of the individual or firm that packs and distributes or sells the fruit for a grower usually begins when the fruit is delivered at the packing house. The association in a general way controls the time of delivery of the fruit of its members to the packing houses and the proportion of their crop that shall be delivered at one time, giving each member an opportunity to furnish his pro rata of fruit during the marketing season, based on the relative percentage of his crop to the holdings of the association as a whole. Previous to the beginning of the investigation by the Bureau of Plant Industry little attempt was made to exercise control over the conditions under which the fruit was harvested and delivered for packing, but during recent seasons much careful attention has been given to these important operations.

In most cases the fruit is picked by the owner or manager of a grove, or by labor under his direction, the labor being paid by the box or by the day. Frequently the fruit is picked and carted to the packing house by contract at a fixed price per box or rate per hundred pounds. Among the cooperative associations and individuals or firms shipping for growers or buying for cash, a system of gang picking is growing in favor as a means of insuring greater uniformity in the condition of the fruit. A picking crew with a foreman is employed by the officers of an association, for example, and the fruit of the members of the association is picked by this crew. Under this system only skillful workmen need be employed and very efficient work is secured when the labor is directed by a competent foreman. Some association packing houses that do not have a picking gang employ a picking inspector, who sees that the fruit delivered by different growers to the packing house has been carefully picked.

The most uniform results are secured when the same labor is employed continuously. Since two or three pickings of oranges are made from the same tree during a season, this condition is not always practicable on the average ranch when the picking is done by the owner. Usually the owner has to secure such labor as is available for each picking, and often can not employ the same set of men more than once. This is especially true where the help is secured through labor agencies. Under these conditions there has been a lack of uniformity in the condition of the fruit from different groves and from the same grove at different pickings.

Among the laborers are found Americans, Japanese, Mexicans, Chinese, and a few of other nationalities. Experience has shown that the ability of the labor foreman is of more importance than the nationality of the crew in securing efficient work and that the general policy of those who employ the labor in respect to the care with which the fruit is to be handled is of greater importance than both.

PICKING CITRUS FRUITS.

In picking citrus fruits it is necessary to sever them from the branches with sharp clippers or shears. The fruit is then placed in a picking bag holding from 20 to 50 pounds, slung over the neck and shoulders of the picker. From this it is emptied into picking or lug boxes, and in these the oranges are delivered to the packing house. Sometimes the packing or shipping boxes are used for this purpose once before shipment. Formerly the most common type of shears in use was a small one with sharp-pointed, curved blades, shown in figure 1, A, which, when not handled with care, often punctured or cut the skin of the orange. Since greater care and attention have been given to the operation of picking, many new styles of clippers have been invented and put into use, most of them with rounded or blunt points. Blunt-pointed clippers are shown in figure 1, B, and another style, known as sheath clippers, in figure 1, C.

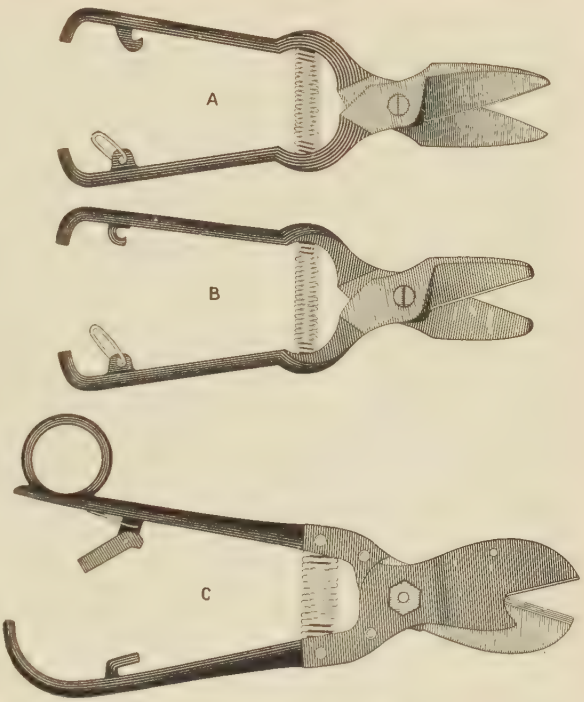


FIG. 1.—Types of shears or clippers used in picking citrus fruits. A, a sharp-pointed type; B, clippers with blunt points; C, sheath clippers.

PACKING CITRUS FRUITS.

The packing houses are located either on the ranches or at the shipping stations, usually at the latter points. Some of the large corporations and a few individuals have the fruit packed in houses on the ranch, but the association houses and those of the other types of shippers are generally placed alongside the railroad at the shipping point.

The houses vary in capacity from 1 to 15 carloads of fruit a day. The capacity of all the packing houses in California is said to aggregate from 400 to 600 cars a day, though the daily shipments do not average more than 150 cars during the main shipping season. In no other fruit industry have the appliances for handling the fruit in the packing house been so highly developed. The average orange packing house is equipped with box-making machines which nail together the boxes used for carrying the fruit to market; specially constructed hand trucks for moving several picking or shipping boxes at a time; hoppers for receiving the fruit; washing tanks and scrubbing machines to remove the sooty-mold fungus, and drying racks in those sections where the fruit has to be washed; elevators to carry the fruit to the grading and sizing machines, drying racks, and other places; carrying belts or chutes; automatic weighing and recording scales for weighing the different grades of fruit of each grower; series of padded bins, sometimes with self-adjusting bottoms, for receiving the different sizes of fruit; belts to carry the packed boxes; presses for covering the boxes; and sometimes a system of fans to assist in drying the fruit, and a machine to wrap the fruit automatically. All of the stationary machinery is run by power, making the interior of a large packing house in operation resemble the interior of a complex factory.

There is a wide variation in the type and arrangement of the different kinds of machinery. A general idea of the steps through which the orange passes may be gained from the following brief description of a common type of house. The fruit is dumped from the field boxes into the hopper (see Pl. IV, figs. 1 and 2), which leads to rapidly revolving brushes (Pl. IV, fig. 1) which clean the fruit. From the brush the fruit is elevated to a sorting or grading table or grading belts, figure 2, where it passes before the grader and is sorted into two or more grades by hand. Each grade then runs by gravity or on belts through an automatic weighing machine (Pl. V, fig. 1), where the weight of the grades of each grower is recorded, to the long sizing machine (Pl. V, fig. 2), and from there, in various ways, to the packing bins seen in Plate VI. If the fruit is to be washed, it is first dumped into a tank of water; then run between brushes submerged in the water (Pl. VII, fig. 1) or with water run-

ning over them; then elevated or run to drying racks (Pl. VII, fig. 2) or under a blast of air, after which it is usually run through all the steps described for brushed fruit, or the hopper and brush may be left out and the oranges delivered to the sorting table. There is a wide difference in the simplicity or complexity of arrangement of the packing houses and a similar variation in the speed with which the machinery is operated. A complex, undesirable type of house is shown in Plate III, figure 2, while a simpler and desirable arrangement of the machinery is shown in Plate VI.

The packing of the fruit is done by men or women, the laborer being paid usually by the box, though sometimes by the day. The packers average from 40 to 100 boxes for a day of ten hours.

FIG. 2.—Grading belts used in assorting oranges.

The grading of citrus fruits is based on the general texture of the skin of the fruit, on its appearance as influenced by scars, and on the general form and style of the fruit. The grades have no reference to the size of the fruit. There are usually three grades packed—"Fancy," "Choice," and "Standard." Some packers also have so-called "Extra fancy" and "Extra choice" grades. A "Fancy" orange is supposed to have a deep orange color, to be normal in form, fine in texture, with freedom from blemishes, and heavy and juicy. A "Choice" orange is supposed to have good color and good but not the finest texture. It may have a few blemishes. It should be free from frost damage and should be reasonably heavy and juicy. A "Standard" orange may be quite badly scarred or

discolored, coarse in texture, and irregular in form, but should be merchantable shipping stock. Many frozen oranges are shipped as "Standards." A fourth grade, "Culls," is sold to the peddlers from the packing houses and is sometimes shipped to near-by markets. Many of the shippers are discarding the "Fancy" and "Choice" grades and pack a grade called "Orchard run," which represents the fruit of the orchard with the "Standards" and "Culls" out. The grades are usually shipped under brands which are selected for the different grades and not under the designation "Fancy," "Choice," or "Standard." The name "Orchard run" is frequently used as a brand designation for that grade.

Each grade of oranges is divided into sizes, the extreme range of sizes varying from 48 to 420 oranges to the box. The most desirable commercial sizes of the Washington Navel variety are in boxes containing 150, 176, 200, and 216 oranges. A standard box of California oranges is 12 by 12 by 26 inches outside measurement, divided in the middle by a partition, with an inside fruit space of $11\frac{1}{2}$ by $11\frac{1}{2}$ by 24 inches. A box of oranges is estimated to weigh 72 pounds.

A car of Washington Navel oranges, so far as the sizes are concerned, may contain boxes of all of the sizes. A car is called a "standard car" when it contains not more than 10 per cent of each of the following sizes—96, 112, and 250, and not over 20 per cent of the 126 size. The remainder of the car may be divided among the 150, 176, 200, and 216 sizes. If a car is sold to a dealer at a fixed price per box, it is usual to allow a discount of 25 to 50 cents per box on the excess in the 96, 112, 126, and 250 sizes, and a discount of 50 cents per box on the 48, 64, 80, 288, 300, 324, 360, and 420 sizes. The rule regarding the sizes in a standard car may vary with the season, with the section, and with the general size of the fruit taken as a whole. When oranges of either the large or small sizes are scarce they are at a premium, and the proportion in a car may be raised without discount.

SHIPPING CITRUS FRUITS.

The citrus fruits of California are distributed to markets throughout the United States and Canada, and to a limited extent to European and other countries. They are shipped under a specially organized refrigerator-car service. From November to the middle of March, during which period about one-half the crop is moved, the weather in California and throughout the territory en route to distributing points is cool and shipments are made under ventilation without ice, the ventilation of the cars being regulated by the railroad under instructions from the shipper. After the middle of March cool weather in California or in transit can not be relied upon and ice is quite generally used for refrigeration, though some ship-

pers forward the fruit much later under ventilation. Early in the season, especially during January and February, when the fruit is packed in a cool condition, it may be frozen in transit unless special precautions are taken to protect it by insulating the car with building paper or other materials, by raising the boxes on strips above the floor, and by regulating the ventilators carefully according to instructions. Occasionally after the middle of March the fruit may be loaded at a temperature of 80° to 100° F., but a large proportion of it is packed at a temperature not above 65° F. even as late as the first of June.

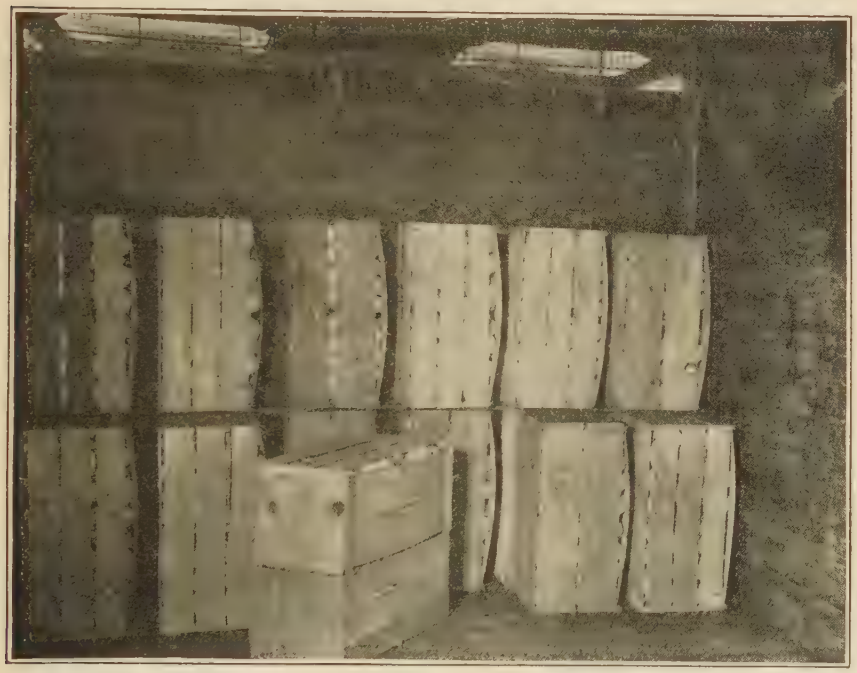


FIG. 3.—Boxes of oranges in a car, showing the standard method of loading.

A standard car 40 feet in length usually contains 384 boxes of oranges loaded two tiers on end and six rows wide, as shown in figure 3. The boxes are billed at an estimated weight of 72 pounds each. The minimum freight weight of a car over 37 feet in length, outside measurement, is 26,700 pounds. The minimum freight weight of a car 37 feet or less in length is 24,190 pounds. The freight rate varies from $1.12½ to $1.50 per hundred pounds when shipped in carload lots. To most points on the Missouri River and eastward there is an emergency rate of $1.15 per hundred pounds in carload lots, effective since March 11, 1907, the former rate being $1.25 per hundred pounds.

In 1907, when there was serious shortage in the supply of cars, many were loaded seven rows wide on the bottom tier and six wide on the top tier as a temporary expedient, thereby increasing the customary load an appreciable amount.

Each of the two ice bunkers of a refrigerator car, one at either end, holds from 2 to 2½ tons of ice. The first icing of the cars is done at various assembling points in California after the fruit is loaded, and reicing in transit follows as needed. The average time in transit from southern California points to New York is twelve to fifteen days, and to Chicago from nine to eleven days, the time, in general, depending on the condition of the transportation business of the western railroads and their connections. The carload rate on refrigeration is based on the section of the country into which the car is shipped and the weight of fruit in a car. The rate to Chicago, for example, on a car of 24,190 pounds is $54.67 and to New York $65.61. The rate on a car of 27,650 pounds, which is the weight of a standard car of 384 boxes, is $62.50 in the former case and $75 in the latter.

THE INVESTIGATION OF THE CAUSES OF DECAY.

The investigation by the Bureau of Plant Industry was begun as the result of the efforts of Mr. J. H. Reed, an orange grower of Riverside, Cal., who, on account of the interstate nature of the problem, endeavored to induce the Department of Agriculture to undertake this work. In the winter of 1903–4 a preliminary survey of the orange industry was undertaken to make plans for this investigation. The causes of the decay were not understood, but a multitude of theories were advanced by growers and shippers to explain it. Some attributed the decay to the influence of the type of soil and to other conditions under which the fruit was grown; to a possible degeneracy in the fruit as the trees grew older, and to climatic conditions, such as frequent fogs and rains. The decay was thought by many to be especially related to a supposed inherent weakness of the fruit during the blooming period of the trees, which occurs during the picking season. Others believed it to be due to methods practiced in the packing houses, while nearly all were more or less agreed that a large part of the loss was chargeable to inadequate or improperly handled transportation facilities. The decay entailed a heavy loss on the shipper, it was detrimental to the reputation of the industry, and it led to difficulties of various kinds between all parties concerned in the handling and transportation of citrus fruits.

The preliminary survey in the winter of 1903–4 showed that the decay was more troublesome in some regions than in others, that it was worse in some packing houses than in others in the same region,

and that it usually increased in severity as the season advanced. Continual observations on many of the popular and supposed causes did not give promise of a satisfactory explanation, but it was noticed from the beginning that there was a close and constant relation between the various methods of handling the fruit and the development of decay.

THE BLUE MOLD OF CITRUS FRUITS.

The common blue-mold fungus was always found to be associated with decaying oranges, as was observed in 1905 by Woodworth.[a] This fungus grew within the tissues of the fruit and caused a breaking down of the structure, which rapidly produced a soft decay of the entire fruit. Two distinct kinds of growth were constantly found. The most common grew rapidly in a rather indefinite area over the orange, producing a mass of olive-green spores, with a large area of white mold extending beyond the spores and producing a semisoft condition of the fruit. The growth of the second was much slower and in a more definite area, and the spores were bright blue in color, though in other respects this fungus was similar to the first.

Both fungi have been determined as species of Penicillium. While a distinct difference can be seen in the growth of the two in producing decay in the orange, it has been difficult to separate them morphologically. *Penicillium glaucum* has been generally considered the most common of the mold fungi. Yet, on the orange the rapid-growing, olive-green fungus is referred to as *Penicillium digitatum*, and the slow-growing, bright-blue species as *P. glaucum*.[b] The more common form is shown in Plate I, frontispiece. The spores are produced in countless numbers on the decaying fruit, of which there is always more or less in the groves and in and around the packing houses. They are on the fruit, on all the machinery, and floating in the atmosphere, and they germinate easily and quickly wherever the conditions of heat and moisture are favorable. That there might be no question about these molds being the cause of the decay, large numbers of fresh, sound oranges were inoculated both in the field and the laboratory with spores of these species, and without exception the characteristic decay resulted.

These fungi had always been considered as saprophytic—i. e., capable of growing only upon dead organic matter—and from previous investigations with apples in storage it had been determined that

[a] Woodworth, C. W. Orange and Lemon Rot, Cal. Agr. Expt. Sta. Bul. 139.

[b] Smith, Ralph E. The "Soft Spot" of Oranges, Botanical Gazette, vol. 24, p. 103.

Smith, Ralph E., et al. The Brown Rot of the Lemon, Cal. Agr. Expt. Sta. Bul. 190.

fungi of this group were apparently incapable of penetrating the unbroken epidermis of a healthy fruit and causing decay.

Upon careful examination of a large number of oranges in which the rot was just starting, it was seen that the area of decay in most cases was around a place where the epidermis had been previously injured by a cut or abrasion of some kind. Not all fruits in which the epidermis had been injured showed decay, nor could the decay always be traced to an abrasion in the skin. Injured fruit that was exposed to a free circulation of air did not usually develop a large amount of decay. The moving air quickly evaporated the moisture which accumulated in the injured tissue, making conditions unfavorable for the germination of the mold spores and the subsequent development of decay.

The effect of different kinds of cuts and abrasions on the fruit appeared important. A slight puncture or the removal of bits of the epidermis by scratches or by shaving it with the picking shears would frequently dry before spores could germinate and become established. A deeper wound, especially in the body of the fruit, where the skin is thin, would usually fill with juice and provide ideal conditions for rapid decay. It was noticed that decay did not develop in these slight wounds, while it was almost sure to develop in the deeper wounds unless the fruits were held in an unusually dry or cold atmosphere.

These observations were followed by a series of laboratory studies by Mrs. Flora W. Patterson, Mycologist of the Bureau of Plant Industry, who found that the blue-mold fungus did not have the power of penetrating the epidermis of a sound, healthy orange even under conditions of heat and moisture that were most favorable for the growth of the fungus. Practical applications of these laboratory tests were made with oranges under ordinary packing-house conditions. Without puncturing the skin, the mold spores were placed on the surface of oranges which had been delivered at the packing house in the usual commercial way and were apparently sound. This fruit was held for one or two weeks in the house, where conditions were favorable for the germination of the spores and for the development of decay, and then examined. It was rare to find that decay had developed at the point where the blue mold had been placed on the fruit. Decay, however, sometimes developed where no mechanical injuries were visible. In these cases, the mold probably entered the skin through injuries caused by the punctures of insects, by the dropping of the fruit, or through other injuries not discernible.

The power of the fungus to grow in healthy oranges in commercial cold storage has been tested by inoculating fresh fruits with the

mold spores in a puncture through the epidermis and placing them at once in a temperature of 32° F. or less. Decay had not developed in two months, when the tests ended. When the decay is established and developing in an orange, it does not appear to be entirely checked when placed in a temperature of 32° F., though the development is greatly retarded.

MECHANICAL INJURIES RELATED TO THE HANDLING OF ORANGES.

In the spring of 1905 a systematic series of observations and inspections was inaugurated to determine the amount and severity of mechanical injuries of oranges when delivered at the packing houses and the relation of the methods of handling the fruit to these injuries.

This was accomplished by a close inspection of many thousand fruits in a large number of packing houses and groves in different sections, and included an examination of the oranges of different growers delivering fruit at the same house and of the work of different pickers working in the same grove.

It was soon discovered that fresh mechanical injuries could be seen on a considerable proportion of the fruit. The most common type of injury was made by the point of the clippers in cutting the oranges from the trees. In some cases deep gashes had been cut into the skin, in others the skin had been shaved or sliced off in areas varying in extent, while in still others the injury was so slight as to be hardly perceptible. Many of the oranges were severely injured by stem punctures, which are produced when an orange cut from the tree with a long stem is allowed to fall or roll forcibly against another fruit, while others showed scratches of various kinds and punctures from thorns. Other common forms of injury occurring in the groves were punctures and bruises from gravel and twigs in the bottom of the picking boxes and cuts in the skin caused by the finger nails of the pickers. Frequently bruises were found that could be traced to rough and careless work in loading and carting the fruit from the groves to the packing house and in unloading. It was found that there was often a wide difference in the amount of this injury in the fruit delivered by different growers to the same packing house, and there was as great a variation in the condition of the fruit in different picking boxes coming from the same grove. Very often there was considerable injury that could be traced to some incidental derangement in the packing-house machinery, such as a broken wire in a wash tank, a protruding screw among the bristles in the brushing machines, a nail or bolt extending into a chute or runway, or some other similar defect. (See Plate I.)

A large number of records of these different types of injuries has been secured during the past three years. It is not possible to include these records in full in this publication, but the following representative statistics will give an idea of the extent of this trouble.

THE EXTENT OF THE MECHANICAL INJURY OF THE ORANGE.

In 1905 the average amount of mechanically injured fruit, based upon a careful inspection of more than 40,000 oranges during January and February, was 17 per cent. On February 27, 1905, a circular was issued calling attention to this injury and its relation to decay and suggesting methods whereby it could be reduced. Apparently the growers were quick to adopt ways of reducing the injury,

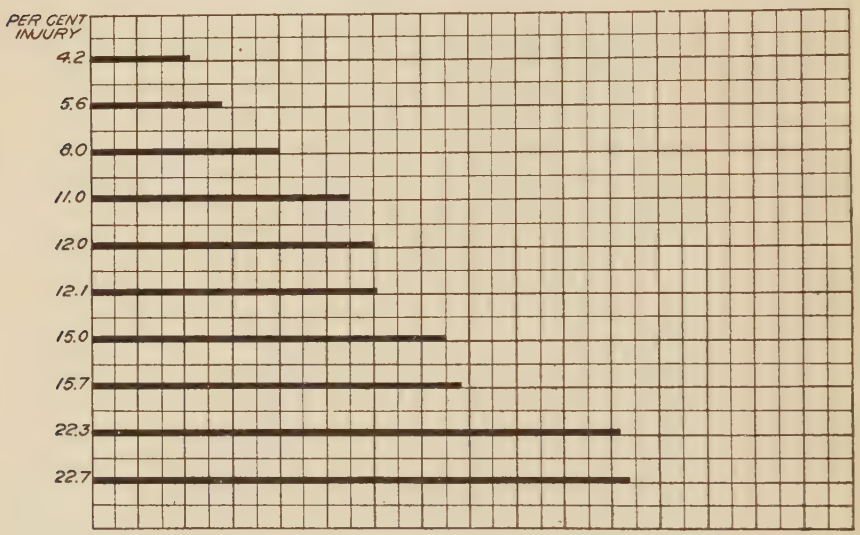


FIG. 4.—Diagram illustrating the average amount of mechanical injury in oranges in ten packing houses.

for after the 1st of March it did not exceed 7.5 per cent—an immediate reduction of nearly 10 per cent.

The accompanying chart (fig. 4), computed from the data of 1905, shows the variation in the amount of injury in the fruit found in ten different packing houses.

The chart shown as figure 5, page 25, also computed from the records of 1905, shows the variation in the amount of injury in the oranges of ten different growers who delivered and pooled their fruit together in the same packing house.

The fruit of an individual has sometimes shown 50 per cent or more of mechanically injured oranges.

The variation in the quantity of fruit injured by ten different pickers in the same grove is brought out in figure 6 (p. 26), computed from the records of 1905.

Occasionally pickers have been found who have injured from 50 to 75 per cent of the fruit they picked.

A large quantity of fruit has been examined in the bins and packed boxes in many packing houses to determine whether the oranges that are injured are seen and removed by the graders, as it was generally maintained that this was done. Figure 7 (p. 27) shows the percentage of injured fruit in ten representative lots.

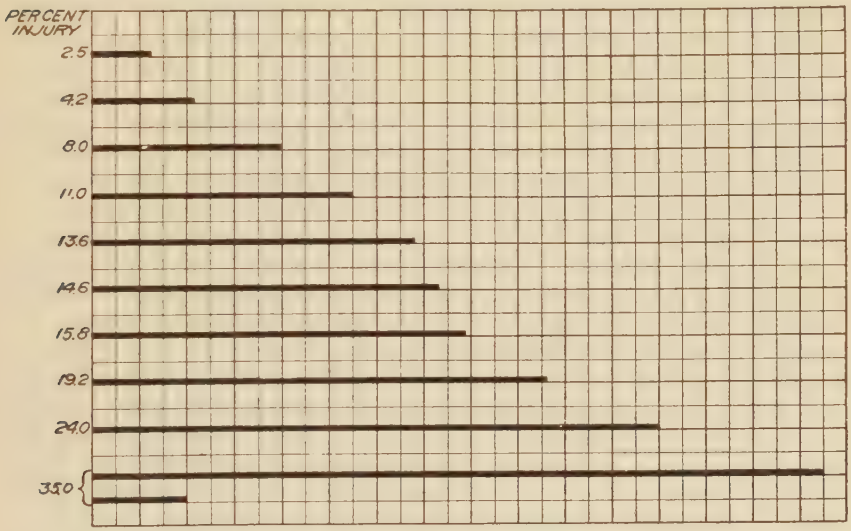


FIG. 5.—Diagram illustrating the average amount of mechanical injury in oranges of ten growers who pooled their fruit.

It was an exception to find a grader who could see and throw out an orange showing a slight mechanical injury. It is probable that 95 per cent of the fruit injured in handling is included in the packed fruit.

GROWERS AND PACKERS NOT AWARE OF THE EXTENT OF MECHANICAL INJURY.

The most experienced growers and packers were not aware of the extent to which the orange was injured in handling, nor did they appreciate the effect of a slight bruise or abrasion on the keeping quality of the fruit. In a general way, it was known that an orange with a punctured skin was likely to decay, and the need of handling the fruit carefully was discussed abstractly but with little appreciation of the importance of careful handling to the preservation of an

orange. The greatest amount of injury was frequently found in the fruit of individuals who were skillful growers and who gave careful attention to all the necessary details of production, but who did not know or understand the importance of careful picking. The same failure to appreciate the importance of care in handling was even more pronounced in the case of the laborers who did the picking. They did not know they would cause the decay of the fruit by cutting the skin or allowing it to drop into the picking sack, or that they were actually causing so much injury to the fruit.

Since it was desirable to have all the persons interested realize the large quantity of fruit that was injured by handling, the inspections of the oranges in the groves and packing houses have been

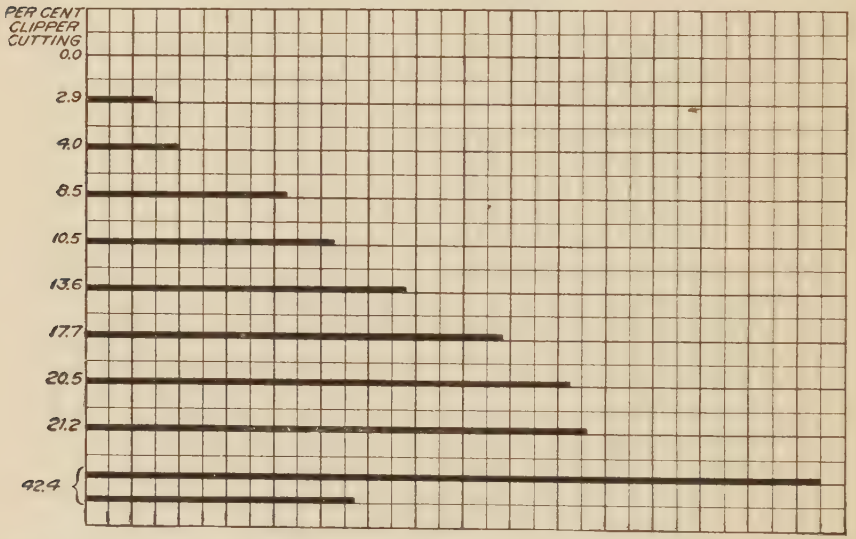


FIG. 6.—Diagram illustrating the average quantity of fruit cut by ten pickers in the same grove.

made in full view and with the cooperation of the most interested growers and packers. The relation between an injury to an orange and the chance of decay during shipment is now generally understood by growers and packers, largely as a result of these demonstrations.

As a result of this understanding, it is now accepted without question that the elimination or reduction of the mechanical injury of the orange in handling is one of the largest problems that the California citrus-fruit grower and packer have to overcome. A determined effort is being made to reduce the trouble, and abundant data have been accumulated to show that by using care in the instruction and supervision of labor not more than 2 or 3 per cent of the

oranges will be injured in handling the fruit on a large commercial scale.

The following data are presented to show that it is practicable to handle the orange without mechanical injury to the fruit. These figures show the result of 10 inspections of fruit from 1905 to 1907, inclusive, of a corporation handling several hundred acres of groves. The first inspection was made before the circular of February 27, 1905, was issued.

Percentage of mechanical injury to fruit found in a large orange grove at each of ten inspections during 1905-1907.

First inspection.	Second inspection.	Third inspection.	Fourth inspection.	Fifth inspection.	Sixth inspection.	Seventh inspection.	Eighth inspection.	Ninth inspection.	Tenth inspection.
15.8	2.6	0.4	1.1	1.2	3.3	5.5	0.3	3.0	0.0

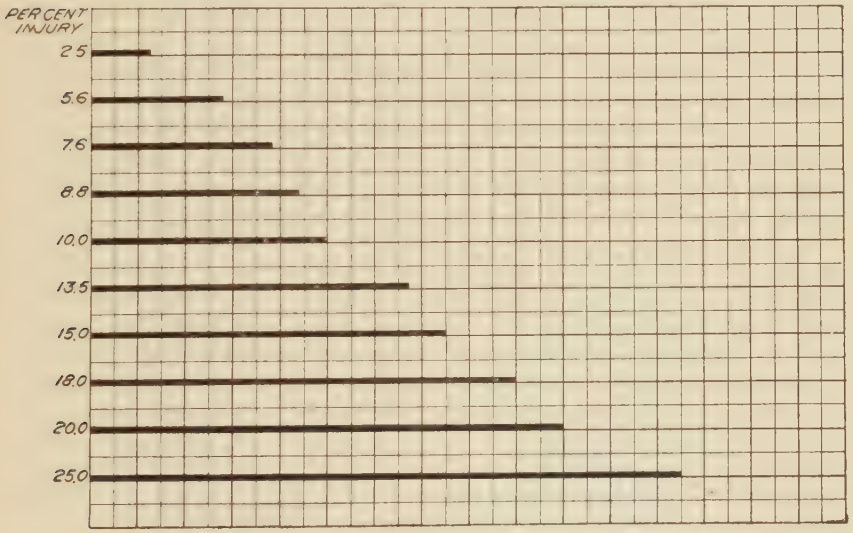


FIG. 7.—Diagram illustrating the average quantity of injured oranges found in bins or packed boxes.

THE INJURY OF THE FRUIT AN ECONOMIC PROBLEM.

After a careful study of the problem for three years, it is evident that the mechanical injury of the orange is partly inherent to the handling of a perishable crop, but that it is primarily related to the economic and social conditions surrounding the citrus-fruit industry. It is related to the large volume of business handled by growers and packers, to the character and quantity of the labor available, to the system of handling the labor, to the details of packing-house management, to the aim of the association and packer who handle

the fruit, and to the effect of sharp competition between those who handle the California citrus-fruit crop.

The industry has reached its present condition through gradual development. The one factor in this growth that stands out with prominence as a fundamental cause of careless handling is the effort to handle large quantities of fruit at the lowest possible cost. By having the fruit picked and packed by the box and by having other operations performed on the same principle, there have been developed labor methods, packing-house equipments, and systems of business practice that place a high premium on the quantity rather than the quality of the work accomplished. The payment of labor by the box has developed a class of pickers whose chief aim is to pick the greatest possible number of boxes. It is not unusual to see the professional picker, with a hoop fastened in the top of the picking sack to hold the mouth open, with a deft movement of the clippers cut the oranges and shoot them directly into the bag. Such effort led to the use of sharp-pointed clippers, or shears (fig. 1, a), which the picker could handle with great facility. It has developed the type of packing-house equipment shown in Plate III, figure 2. It is responsible for overcrowding the capacity of the average packing house, for the excessive speed of machinery, and for a general feeling among growers and packers that the continuous reduction in the fixed charges in the handling of the crop in California from year to year is an essential in successful orange handling. It is a common occurrence for a grower to change the agency for handling his fruit to another that will do it for a fraction of a cent a box less, the immediate saving being the factor that determines his action. There is an equal rivalry between the packing houses to reduce the cost of handling the fruit, and a similar desire to have it sold at the lowest charge for handling.

A REDUCTION IN THE COST OF HANDLING A PERISHABLE PRODUCT NOT ALWAYS JUSTIFIABLE.

The tendency to reduce the cost of producing and handling a crop is commendable from a business point of view. Probably no other fruit industry has reduced the necessary cost of handling and marketing the crop to such an extent as the citrus industry, largely as a result of the effective cooperative organization of the fruit growers. But in the handling of a perishable commodity it is false economy to reduce the cost of an operation if the change is detrimental to the keeping quality or attractiveness of the product. A laborer who picks 100 boxes of oranges a day at 3 cents a box, cuts 25 per cent with the clippers, and drops the fruit several feet into a bag is more expensive to the grower than one who picks 40 boxes for $3 but

places the fruit in the picking boxes in sound condition. It is equally false economy to have the oranges packed at low cost in a house where the handling of the fruit is so rough and complicated as to make it susceptible to decay before it is loaded for shipment. The real economy of reducing the cost of an operation is determined by the effect on the keeping quality of the product. Every reduction that is made at the expense of the shipping and keeping quality of the fruit is not a saving to the industry, but in the end acts as an increase in the cost of handling by reducing the value of the fruit. Later in this bulletin it will be shown that the highest net returns in the citrus industry have followed an increased cost to insure a more careful handling of the product.

A WEAK POINT IN THE PRESENT METHOD OF HANDLING THE ORANGE.

There is another factor related to the cooperative method of handling, as well as to the method of handling the fruit by buyers and shippers, that is responsible for a large amount of rough handling. Neither the association, the shipper, nor the buyer can insure the careful handling of fruit where the picking and hauling are in the hands of the growers or of their representatives. In a general way, the packing association or shipper can advise the grower how to pick and haul the fruit, and lots of fruit that have been grossly mismanaged may be rejected; but it is impossible to insure a uniform condition in the fruit of different growers under these conditions. There is little incentive for the grower to handle his fruit with unusual care if it is to be pooled with the fruit of other growers who handle it carelessly. The tendency is for all growers to handle the fruit with but average care and for the careless grower to depend on a higher average handling by others to overcome the shiftless methods on his ranch. It is the tendency also for the average grower whose fruit is packed and sold for him by a dealer or agent to reduce the cost of picking and hauling the fruit to the packing house to the lowest possible figure, and if the fruit decays as a result of this bad handling to attribute it to the methods employed by the dealer or agent in packing and selling the fruit. A cooperative association or a dealer who handles the fruit for the growers either under a pooling system or for individual account needs to establish a standard condition as to freedom from mechanical injury of the fruit that enters the packing house and to provide a practical method of enforcing the requirements.

METHODS OF INSURING A UNIFORM CONDITION OF THE FRUIT.

There are at least two methods that may be adopted as a means of insuring a uniformly small percentage of injury in the fruit of different growers. The first is the picking of the fruit by gangs of

laborers under the control of the packing-house management. A number of cooperative associations and independent shippers have recently adopted this method of handling the fruit. The success of this plan depends on the cooperation of the growers, a tactful and efficient labor foreman, and the strong support of the foreman by the packing-house management to the end that the fruit may be picked carefully and economically. If the growers do not accept this plan cheerfully, if the picking foreman is inefficient, or if the packing-house management insists on reducing the cost of picking without regard to the effect on the condition of the fruit, such a system is doomed to failure.

A second, though less certain, means of securing a uniform condition of the fruit is by a system of inspecting the fruit in the groves and as it comes to the packing houses, in order that the persistently careless picker and grower may be located and advised as to the means of reducing the injury, and finally eliminated if his fruit does not reach the required standard. This system has already been adopted by a number of association houses and by a few independent shippers.

EXPERIMENTS WITH DIFFERENT METHODS OF HANDLING ORANGES.

The experimental investigation of the causes of decay in oranges has been conducted with a view to determining the following points: (1) The comparative susceptibility to decay of oranges handled in different ways for shipment after holding the fruit in the packing houses in California about two weeks; (2) the comparative susceptibility to decay of oranges handled in different ways for shipment when forwarded to New York under ventilation, icing, and precooling; (3) the comparative susceptibility to decay of oranges handled in different ways and shipped under different conditions, the decay being determined at intervals during a storage of the fruit in a common storage room in eastern markets.

Technical investigations in refrigeration, including the development and testing of various methods of cooling the orange for shipment and a determination of the changes in the temperatures of cars during the transcontinental trip when shipped under different methods, such as ventilation, icing, and precooling, have also been made.

THE EXPERIMENTS WITH ORANGES STORED IN PACKING HOUSES.

The primary object of the experiments with oranges stored in packing houses was to determine, under conditions that permitted the growers and packers to see the results, the comparative suscepti-

bility to decay of fruit that had been handled in different ways. A secondary object was to determine the comparative amount of decay in oranges handled similarly in different regions of the citrus-fruit belt.

The method of conducting these experiments was to select a quantity of apparently sound oranges from the picking boxes just as they were received from the grove, designating this lot as "unbrushed:" another lot of apparently sound fruit that had been run through the brushing machine and selected from the packing bins was designated as "brushed:" a third lot selected from either the drying rack or the packing bins, or that had been especially washed, was designated as "washed," and a fourth lot, in which each orange showed a visible injury, such as a clipper cut, punctures of various kinds, or other abrasions, was designated as "mechanically injured." In 1907 a comparison was made between the amount of decay of oranges washed in clean water and fruit washed in dirty water, similar to that used in commercial washing, or in clean water in which some blue-mold spores had been mixed. Several boxes of fruit of each lot were packed at one time and the fruit was left in the packing house for about two weeks, when it was examined for decay in the presence of growers and shippers.

These experiments were started in 1905 in 6 houses. In 1906 they were carried on in 15 houses and in 1907 in 31 houses. The experiments were usually begun in January and extended into April.

The work of the three years has shown that the orange as it comes from the tree in sound condition seldom develops decay and that brushing, washing, and the mechanical injury of the fruit in handling are followed by more or less loss, the greatest decay developing in the mechanically injured oranges.

The following table gives the average decay in the different lots of fruit in the three years. The data of 1907 appear also in figure 8, page 32.

TABLE I.—*Average percentage of decay found in oranges subjected to various methods of treatment and in various conditions, held in packing houses in 1905, 1906, and 1907.*

Year.	Treatment or condition of oranges.				
	Unbrushed.	Brushed.	Washed in clean water.	Washed in dirty water.	Mechanically injured.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1905	4.9	10.3	.....	.....	29.0
1906	1.5	4.7	.....	10.3	36.8
1907	2.9	6.6	3.9	17.8	40.1

It should not be inferred from these figures that the unbrushed fruit in 1906 was less susceptible to decay than in 1905 or 1907. The fruit used in the experimental work was selected not by microscopic

examination, but by an inspection not more critical than a careful fruit grader could make. The fruit that appears to be sound may nevertheless be bruised to some extent, and although the bruises are not easily perceptible they are severe enough to be followed by the blue-mold decay. The inspection in 1905 was probably not as critical as the work that followed, on account of the comparative inexperience of the Department representatives. The important principle underlying these figures is that an apparently sound orange when it comes from the tree shows greater resistance to decay than the same fruit after it has been handled in different ways, that the fruit showing visible mechanical injury as a result of handling develops the maximum decay, and that the brushing and washing of sound oranges is more or less detrimental to their keeping quality.

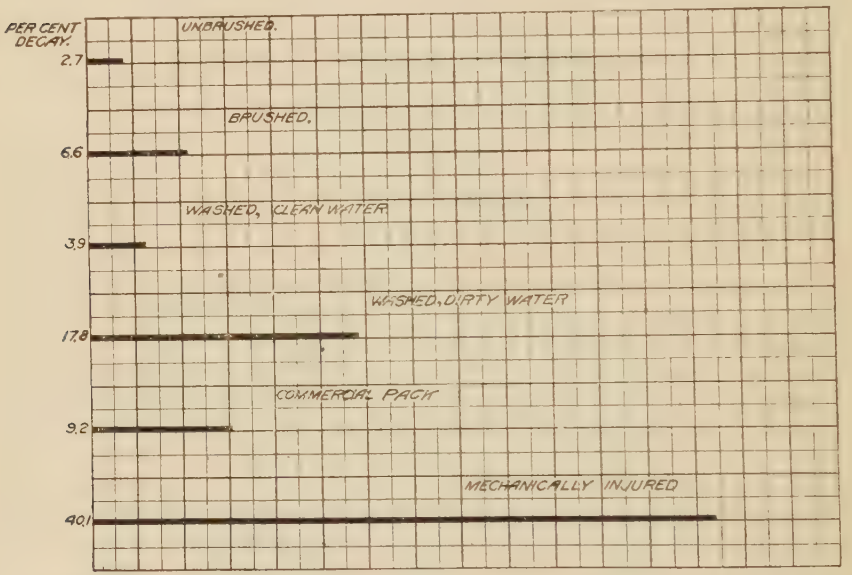


FIG. 8.—Diagram illustrating the percentage of decay in oranges held in packing houses, 1907.

Aside from these experiments, a number of comparisons have been made to determine the effect of dropping an orange 18 inches into the picking box. The data along this line are not extensive or conclusive, but they show that under some conditions the decay may be considerably increased by dropping the fruit a small distance.

THE DECAY IN ORANGES IN DIFFERENT SECTIONS.

The impression is general among growers and shippers in California that there is a wide difference in the inherent keeping quality of the oranges of different sections. The fruit from the upper San Bernardino Valley, for example, is usually said to have better ship-

ping qualities than the oranges grown in the more humid regions near the coast. As a matter of fact, the average condition of the fruit of these two regions on arriving in market probably conforms to this general impression. The results of the packing-house tests already referred to indicate that the difference in shipping quality is due more to the conditions under which the fruit is handled in these sections than to the inherent character of the fruit itself. By comparing the experiments conducted in a group of houses on the coast with those in a group in the upper San Bernardino Valley, the following average result appears:

TABLE II.—*Average percentage of decay found in oranges in different sections of southern California subjected to various methods of treatment and in various conditions.*

Locality where grown.	Treatment or condition of oranges.				
	Not brushed.	Brushed.	Washed in clean water.	Washed in dirty water.	Mechanically injured.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Upper San Bernardino Valley	3.0	4.9	4.7	23.1	36.0
Coast region	3.1	9.1	5.2	16.2	51.1

There is practically no difference in the decay in the unbrushed fruit in the two regions. This shows the keeping quality of the sound fruit just as it comes from the tree. There is some difference in the brushed fruit, as the same types of brushes are not used in both sections, nor are the brushes always handled with equal care. When the fruit is washed in clean water the results are similar, the condition of handling in this case being similar and comparable. There is some difference in the decay in the mechanically injured fruit and in the oranges washed in dirty water, as the nature of the injury and the amount of blue mold in the dirty water were probably not comparable. These differences in decay are no greater than commonly occur in different experiments in handling the same type of fruit in the same house.

In order to compare the influence of the brushing of the fruit under similar conditions, the tests in the houses in each section using the same kind of brush have been brought together. In the upper valley the decay from brushing the fruit was 4.9 per cent and in the coast region 4.3 per cent, or practically the same result. The packing-house tests indicate that an orange with a sound skin is not more likely to decay when grown in the coast region than a similar orange grown in other parts of the orange belt and that a similar line of handling produces similar results in the different regions.

The difference that occurs in the amount of decay in different regions or in different houses in the same region is due primarily to

the conditions under which the fruit is handled. In the coast region in the past a large part of the fruit has had to be washed, while the fruit of the upper-valley districts has been shipped in a dry-brushed or unbrushed condition. Since these investigations were begun, the representatives of the Bureau of Plant Industry have had occasion to look into the conditions in many sections where the fruit developed unusually large amounts of decay. In every case the cause of the trouble has been found to be due to the conditions under which the fruit has been handled, including the influence of such matters as the care with which the scale insects are held in control in the groves, the business capacity of the directors of the association, the ability of the packing-house foreman, the system of handling labor in the groves and packing houses, the efficiency of the labor, the sanitary conditions in the packing houses, and the kind of packing-house equipment. Wherever these conditions have been bad a section has acquired the reputation of producing fruit that has poor shipping quality, and wherever these conditions have been favorable to the proper handling of the fruit there has been no trouble with its condition on arrival at destination.

By these remarks it is not intended to convey the impression that the fruit of all sections is alike. There is the widest difference in the quality, in the time of maturity, and in the color of oranges of different sections and in different groves in the same section. There is probably a good deal of difference in the susceptibility of the fruit of different regions to bruising, as there is a wide difference in the texture of the fruit. What is intended to be conveyed is that there is no practical difference in the amount of decay that develops even in the tenderest oranges of a section when the fruit is handled with enough care to prevent bruising.

THE DECAY IN ORANGES IN DIFFERENT PERIODS OF THE SEASON.

To determine the influence on decay of picking the oranges at different times during the season 20 boxes of the Washington Navel were carefully picked about every ten days from January to May from a grove of the Arlington Heights Fruit Company, Riverside, Cal. The fruit was held two weeks under conditions that were especially favorable to the development of rot. The decay in the fruit picked at different times is brought out in the chart shown as figure 9.

There was practically no difference in the amount of decay in the fruit at any time between January and May. The small amount of decay could usually be traced to mechanical injuries that were overlooked when the fruit was brought in from the groves, and the slight difference in the amount of decay at the different pickings could be

easily accounted for in this way. The trees were in bloom when the fruit was picked on March 23 and April 2.

The data from these tests are not extensive enough to be conclusive, but taken in connection with the other data accumulated they indicate that California oranges picked and handled with enough care to protect the skin from bruising are practically immune to decay, whether picked in a partially ripe or fully matured condition. In this connection the series of shipments of carefully handled fruit from February to May under ventilation, referred to on page 44, does not show an increase in decay as the season advanced.

It is popularly believed that the fruit is more susceptible to decay at the period just preceding and during the blooming of the trees. This belief does not appear to be well founded. The increase in decay that sometimes occurs in the shipments in February or March is probably related to rises in temperature in California at that time, causing the fruit to be loaded in a hot condition. There is often a period of hot weather for a few days each year at this time. The

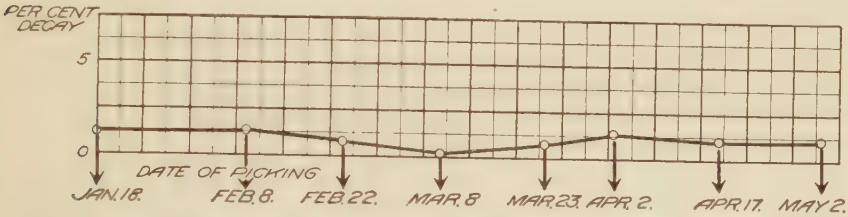


FIG. 9.—Diagram illustrating the percentage of decay in oranges picked at different times during the harvesting season, 1906.

fruit is still being shipped under ventilation. The oranges that go forward at that time from the sections that handle the fruit roughly develop excessive amounts of decay. This may be followed by cooler weather or by the adoption of icing in place of ventilation, and the decay falls off. Whenever the weather remains cool throughout the shipping season there appears to be no unusual increase in the amount of rot at the blooming time.

An increase in decay usually follows an overcrowded condition of the packing houses or a temporary shortage in the supply of cars in warm weather. It may also be serious at the height of the harvesting season. Under the first condition the fruit is handled with less than the usual care and is made more susceptible to rot. Under the second the decay begins to grow in the bruised fruit while the oranges are standing in the packing house. Under the third condition the grower has to employ a large amount of unskilled labor, as there is not enough skilled labor to harvest the crop at the height of the season, and the fruit is delivered to the packing house in poor physical condition.

In the commercial shipments the decay is usually worse in April and May than it is earlier in the season, largely because the average temperature is higher, causing the decay to start quickly, and also because it develops more readily in ripe bruised oranges than in fruit that is bruised but immature.

THE CURING OF ORANGES BEFORE PACKING.

At the time the investigation described in this bulletin was begun, it was a common practice to hold oranges in a packing house a few days before packing. This practice was referred to as "curing." It consisted in the wilting or the evaporation of a small amount of moisture from the skin of the orange, thereby making it more pliable and easier to pack. It was considered necessary to wilt the fruit in order that it might be pressed into place in the packing box without injury and to insure the arrival of the package in market in a tight condition. It was believed that by packing hard, freshly picked fruit the curing or wilting would occur in the box, and the pack would arrive at destination in slack condition. A final claim for curing was that much, if not all, of the decay resulting from mechanical injuries would be sufficiently developed to be noticed and discarded by the graders or packers by holding the fruit in the house a few days before packing.

The general claims for curing have not been found to be well established. Early in the shipping season, when the oranges are immature and the skin hard, wilting or curing undoubtedly facilitates the packing of fruit. Later in the season, when the fruit is ripe, the curing does not appear to improve this condition, as the fruit is naturally pliable. The arrival of oranges in a slack condition in the box is not due primarily to packing uncured fruit. It is the result of packing the fruit loosely and poorly in the box. If each orange is pressed firmly into place by the packer, the fruit can be shipped at any time of year as soon as it is picked, and the packages will arrive in full, firm condition. The average packer does not take time to press each orange firmly in place, especially if the packing is paid for by the box. The packages are filled high and the cover press is expected to do the work that should have been done by the packer. The press, however, only makes the upper layers of the fruit tight in a loosely packed box. The fruit settles during the trip and arrives in a loose condition. These remarks are based on the fact that many of the leading shippers have packed the fruit within twenty-four hours after picking during the last two years without complaint as to the condition of the pack on arrival.

It is not true, either, that the decay develops in the mechanically injured oranges during the curing period except in warm weather and in fruit that is most seriously injured. The decay may start to grow during this time, but it requires several days for it to progress far enough to soften the fruit and to be seen by a grader. The decay is less severe in the unpacked boxes than it is in the packed fruit, in which the moisture given off by transpiration is retained. If fruit can not be shipped quickly after picking it is better to leave it in an unpacked condition.

The curing of the orange does not appear to be detrimental to the shipping quality of sound fruit at any season, or to slightly injured fruit in cool weather. Early in the season it makes the fruit somewhat easier to handle by the packer, but under the conditions pertaining to the commercial handling of the fruit in California it probably does more harm than good by allowing the decay to begin to grow in the mechanically injured fruit. If this fruit soon after picking is shipped under refrigeration or enters cool territory soon after picking, the decay may not start to grow.

THE BRUSHING OF CALIFORNIA ORANGES.

The practice of brushing oranges grew up gradually in California. Practically all of the fruit was being either brushed or washed when the present investigation was begun. The fruit was brushed originally to remove the light coats of sooty-mold fungus or the dust that accumulates from the tillage of the groves in the dry season. The fruit was given a glossy appearance by the brushing similar to the artificial glossiness that is characteristic of the polished fruit sold from street stands. The shipper and the receiver finally considered it necessary to brush the fruit whether it was dirty or not, and brushing became established as a regular packing-house operation even in houses to which the fruit is delivered from the groves in a clean condition.

Several types of brushes have been developed in California. A kind commonly used is shown in Plate IV, figure 1. Some brush the fruit lightly, while the stiff fiber brushes or those not adjustable to fruit of different sizes may brush the oranges very harshly. In the packing-house experiments, the decay has often been raised from 10 to 40 per cent in small lots of fruit run through a brush of a harsh type or through a brush that was improperly adjusted. The injury from the brush generally arises from the inoculation of the mechanically injured parts of the skin with blue-mold spores that are attached to the bristles of the brush or by the actual puncturing of the skin by the bristles and inoculation at the same time in the case of the

harsh types or badly adjusted brushes. It is probable that light brushing is not injurious to sound oranges.

There is a wide difference in the quantity of dust and sooty mold on the fruit of different groves and in different seasons. All of the groves are comparatively free from dust during the rainy season, from January to April or May, and in groves that are well fumigated, and in most of those in the upper part of the San Bernardino Valley the fruit is practically free from the sooty-mold fungus.

It improves the appearance of an orange to have the dirt removed from the skin. It detracts from a moderately clean orange to have the natural bloom replaced by a gloss, and this altered appearance does not improve the selling value of the fruit. It is wholly unnecessary to brush a large part of the California crop, though it may be advisable to brush the fruit that grows on the rows along the highways, or to brush the entire crop after the rainy season is ended and the dust from the tillage of the land settles on the fruit. In Plate IV, figure 2, an arrangement is shown with a removable carrying belt placed on the box containing the brush. This belt carries the fruit from the hopper over the brush to the elevator leading to the sorting table. When a load of fruit requires it the belt is removed and the oranges are run through the brushes.

In 1906 the brushes were eliminated from two or three packing houses, and in 1907 at least a dozen houses, including those that shipped the brands which brought the highest prices throughout the season, forwarded the fruit without brushing.

THE WASHING OF CALIFORNIA ORANGES.

Oranges are washed primarily to remove the sooty-mold fungus that grows in the so-called honeydew exuded by the black scale (*Saissetia oleae* Bern.). The Valencia orange is sometimes washed to raise the grade by making the fruit clean and attractive, and the Washington Naval is occasionally washed with that end in view.

When the present investigation by the Bureau of Plant Industry was undertaken, from one-third to one-half of the oranges of California were washed, practically all of the fruit in some sections being treated in this way, especially where the growers had been overconfident in the parasite *Scutellista cyanea* Matsch or in the use of oil sprays as means of holding the black scale in check.

The honeydew from the black scale spreads out over the branches, leaves, and fruit, and in severe infestations the fungus which grows upon it makes the oranges black and unsightly. The fungus forms a thin skin-like covering over the orange which is removed by washing, or in light attacks by brushing the fruit. A Valencia orange

affected with sooty-mold fungus and one free from the trouble are shown in Plate VIII.

The injury arising from washing the orange is primarily due to the water of the tank becoming infested with spores of the blue mold. These spores are carried into the mechanical abrasions of the skin by the water, under conditions that favor the growth of the fungus. The decay in washed fruit is also increased from the fact that the fruit is handled through a complicated system of tanks, brushes, elevators, racks, and other machinery which multiplies the chances of mechanical injury. A good deal of the fruit is packed before it is thoroughly dry, thereby making conditions of moisture favorable for the development of decay in the packed fruit. This condition arises during cloudy weather when there is not sufficient sunshine to perfect the drying and at times when the fruit is not delivered to the packing house fast enough to keep the packers supplied with dry fruit.

The water is always more or less infected with the spores of the rot fungus. They are found abundantly on the skin of sound oranges and in the dirt from the bottom of the boxes; in practice, also, decaying oranges frequently pass into the tank. This condition becomes aggravated when the water is not changed frequently. It is least objectionable when fresh water is constantly running through the tank or when the oranges are run through brushes with the water sprayed over them. In the average house the water in the tanks was not changed oftener than once in every day or two until 1907, when in many of the houses the water was kept running constantly through the tanks. It apparently is not injurious to the orange to wash it in clean water, provided it is handled carefully in other respects.

The necessity for washing the fruit should be avoided.—The necessity for washing the orange should be avoided by a proper fumigation of the groves with cyanide of potassium or by spraying, if it can be effectively done, rather than by treating the fruit in the packing house. It has often been suggested that the blue mold might be killed by a disinfectant in the wash water, as is done with the parasitic fungus of the lemon which produces the brown rot. This does not appear from preliminary studies to be promising or advisable. If it were possible to kill the blue mold in the washing tank, it would place a premium on the shiftless management of the groves and on the rough, careless handling of the fruit. Fumigation, on the other hand, is one of the operations that promotes good orchard management; it maintains strong, healthy trees and fruit, and it reduces the cost of preparing the oranges for market in a manner that increases the keeping quality of the fruit.

PACKING-HOUSE EQUIPMENT AND CONDITIONS.

The equipment of the average packing house, especially before 1907, was too complicated to permit of careful handling of the fruit. Some part or parts of the equipment were usually out of order, and there were additional chances for injury from the falling or rapid running of the oranges over gravity chutes or runs. Many of the packing houses have not been equipped on good mechanical principles or with proper regard for the effect of the handling of the fruit on its keeping quality. It is not too much to say that there was practically no consideration given to the effect of packing-house machinery and its installation on the carrying quality of the fruit from about 1895 to 1906, the development being made primarily to handle large quantities at low cost. Since 1906 a good many houses have been modified by the installation of a simpler type of machinery. A better idea of the former condition of many packing houses and of some houses at the present time may be had by referring to a typical example of improper equipment.

A prominent house that had the reputation of shipping fruit of poor keeping quality was running the oranges through about a thousand feet of machinery of different kinds. In order to force the fruit through the machinery as rapidly as possible, a boy shoved the oranges into the washing machine with a paddle, the fruit clogging in the machine frequently and becoming crushed. As many as 1,200 boxes were sometimes run through the washer in ten hours. The capacity of the elevator leading from the washer to the drying racks was overtaxed, and the oranges were dropping back into the washer from heights varying from one to several feet. The fruit was frequently shoved down the drying racks with poles, and in practically every rack the oranges were bumping over the heads of nails or slivers of wood protruding into the runways. It was a common thing to see a boy kick the oranges into place when the bins became clogged. In this packing house eleven different places were located where the fruit dropped from 1 to 2½ feet or where the oranges were delivered with force at the bottom of a long gravity chute. As a result, crushed and broken oranges could be found at any time along the runways through which the fruit was obliged to pass. It is a tribute to the shipping quality of the California orange that so large a proportion of the fruit of this house arrived in market in sound condition after this harsh type of handling.

Features to be avoided in a packing house.—It is difficult to point out a single place where fruit is likely to be injured in different packing houses, as the arrangement of the machinery varies widely. There are a few features in the arrangement of every packing house

that ought to be considered. A house should be equipped in the simplest possible manner in order to avoid handling the fruit more than is necessary. The dropping of the fruit or its swift delivery from the carrying belts should be avoided. Overhead sizers and all gravity chutes are to be condemned. The slow-moving, flat carrying belts should take the place of the gravity chute, as in this way the fruit may be carried wherever desired without injury. The gravity sorting table ought to be replaced by a low belt sorting table.

The hopper is a source of much injury from the rough dumping of the fruit from the picking boxes. A hopper ought not to be higher than the brush to which it leads, and the fruit may be carried to the brush by belts extending into the hopper instead of by a steep gravity run. The present hoppers are too high to make the emptying of the boxes easy. The hopper ought to be well padded.

It is a question worth considering whether the hopper can not be eliminated from many houses and the fruit delivered to the sorting belts or on a carrying belt leading to the sorting table. It is entirely practical, if necessary, to deliver the fruit on these belts by taking the oranges out of the boxes by hand.

There is also much injury to the oranges in dropping into and in delivering from the weighing machines and in the drop of the fruit into the packing bins of various kinds, none of which prevents a considerable fall of the fruit when it enters the bin. Another source of injury is the rapid delivery of the fruit from a carrying belt to the elevators, scales, bins, or other part of the machinery to which the belts lead. This defect is the result of the use of narrow belts which have to be run at high speed to meet the requirements of the house rather than the use of wider belts of larger carrying capacity.

There has been a great improvement in packing-house equipment in the last two or three years, but the opportunity for the development of simpler types of houses and equipment has not yet been exhausted.

The handling of the packing-house force and equipment is also an important factor. Unless the packing-house manager is adapted to the handling of labor and can keep the machinery in smooth running order, no amount of improvement in the machinery of the packing house can overcome the bad effect on the fruit of careless, rough, undisciplined labor.

In addition to the need of a simple equipped and well-managed house, the most rigid attention needs to be given to the removal of decaying fruit from the house and its surroundings. It is not uncommon to see rotting oranges in the bins, on the floor, and on the ground around the house. Under these conditions, the houses are

filled with myriads of blue-mold spores. This lack of attention to the cleanliness of a packing house has a bad effect on the labor, and it is invariably accompanied by rough handling and slovenly work in general. On the other hand, there is not a packing house in California that is leading in the careful handling of its fruit that does not use rigid care to keep the house and its surroundings clean and sanitary.

THE DECAY OF ORANGES IN TRANSIT.

GENERAL DESCRIPTION OF THE EXPERIMENTS.

The investigation of the decay of oranges during transportation included 40 shipments in 1905, 70 shipments in 1906, and 187 shipments in 1907. Nearly all of the fruit was forwarded to New York. The leading object of this investigation was to determine the relation of the following factors to the development of decay in transit: (1) Preparing the orange for shipment in different ways in California; (2) forwarding it at different lengths of time after packing, and (3) shipping the fruit under different systems of transportation. An investigation has also been made of the changes that occur in the temperature in refrigerator cars when handled under different conditions during the transcontinental trip, and a number of technical engineering problems connected with refrigeration have received consideration. The shipments have included duplicate lots of apparently sound brushed or unbrushed fruit, of sound washed fruit, of the regular commercially packed fruit, and of oranges showing visible mechanical injuries, such as stem punctures, clipper cuts, and other types of abrasions. The different lots have been packed from the bins from which the commercially packed fruit was taken by careful sorting by representatives of the Bureau of Plant Industry. Duplicate lots of fruit have been forwarded as soon as packed and on the second and the fourth days after packing under (1) ventilation, (2) icing, and (3) precooling followed by icing. The decay has been determined by Bureau representatives by the inspection of every orange on the arrival of the fruit in New York.

Through the cooperation of the shippers and receivers, the fruit for these shipments has been turned over to the Bureau of Plant Industry for experimental use and after inspection in New York has been returned to the receiver. The railroad companies have extended every facility for the study of the conditions in transit, and the cold-storage interests of southern California made it possible to carry on technical as well as commercial investigations of the precooling process.

The result of the shipments of each of the three years has been consistent with the others. It is impossible to record the details of each shipment during the three years. The shipments of 1907, which were on the most comprehensive scale and are most representative of commercial conditions, will be discussed as representative of the entire work.

THE SHIPMENTS UNDER VENTILATION.

The shipments under ventilation began in 1907 in February and extended into May. During February and March the weather was cold in California as well as during the trip across the continent. The temperature of the fruit was not often above 50° F. when loaded, and was frequently as cold as the precooled fruit. On the average, the fruit was probably cooler during the entire trip than the oranges shipped under ordinary icing later in the season. The average decay in the shipments under ventilation, therefore, was comparatively low.

There were two series of shipments under ventilation. The first included apparently sound brushed and washed fruit, commercially packed fruit, and mechanically injured fruit. One-third of each lot went forward as soon as packed and the remainder on the second and the fourth days after packing. This fruit was taken from sections in which the fruit is handled with average commercial care, not representing the roughest type or the most careful type of handling. The fruit was shipped in February. The second series was taken from a single house in which the fruit is handled with care in the groves and in the packing house. It represents the regular commercial pack of the house, the fruit showing on the average not more than 1 to 3 per cent of mechanical injury. The fruit of this house is not brushed. The shipments in the second series began in February and extended into May. The result of the shipments under the first series, shown also in figure 10, is brought out in the following table:

TABLE III.—*Percentage of decay in oranges handled with average care, shipped under ventilation, February, 1907.*

Treatment or condition of fruit.	Decay following immediate shipment and approximate delay of 2 days and 4 days.			
	(None.)	(2 days.)	(4 days.)	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Brushed fruit, apparently sound	1.4	2.2	2.7	2.1
Washed fruit, apparently sound	1.7	3.7	5.1	3.5
Commercially packed fruit	2.1	4.8	5.3	4.1
Mechanically injured fruit	9.4	15.0	21.7	15.4
Average	3.6	6.4	8.7	.....

Two important factors are brought out by these shipments: (1) The oranges that are handled the most simply, i. e., the apparently sound brushed fruit, develop the least decay, while the fruit that is

sorted from the same bins but has been injured in handling develops the greatest amount of decay; (2) the fruit, taken as a whole, that was shipped out promptly after packing developed little decay, while the fruit that was delayed before shipment developed a good deal of decay, the injury from the delay being least severe in the sound brushed fruit and greatest in the fruit that was mechanically injured. The increase in the decay in the apparently sound brushed and washed fruit as a result of the delay in shipping is probably due to the fact that it was not possible to eliminate all of the injured oranges in sorting the fruit from the bins.

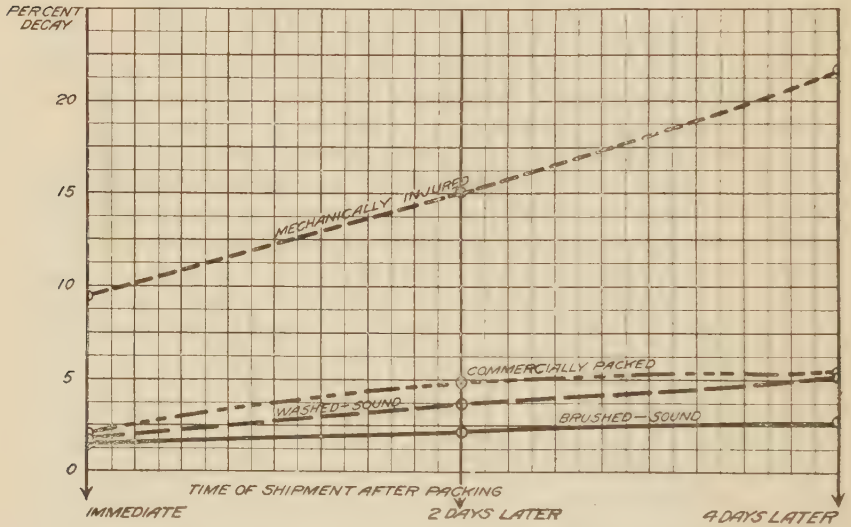


FIG. 10.—Diagram illustrating the percentage of decay in oranges handled with average care, shipped under ventilation, February, 1907.

The result of the shipments under the second series, i. e., of fruit handled carefully in the groves and packing houses, is brought out in the following table:

TABLE IV.—*Percentage of decay in oranges handled carefully under commercial conditions and shipped under ventilation from February to May, 1907.*

Date of first shipment.	Decay following immediate shipment and approximate delay of 2 days and 4 days.			
	(None.)	(2 days.)	(4 days.)	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
February 26	0.7	0.8	1.3	0.9
March 19	1.8	1.7	1.8	1.8
April 1	1.0	1.9	2.3	1.7
April 19	0.8	1.4	2.7	1.6
May 1	2.7	1.7	2.7	2.4
Average	1.4	1.5	1.9	

This table shows that oranges can be handled in a large commercial business with enough care to insure the arrival of the fruit in market in sound condition when shipped under ventilation through a large part of the Washington Navel shipping season. It also shows that there is little practical difference in decay in sound fruit shipped in February or in the succeeding months. As the fruit of this house has shown no better inherent keeping quality than other sound fruit from the same region, a brief description of the methods employed in handling the crop will be useful in showing how a crop is carefully handled in a large commercial business.

Methods used in preventing decay in oranges in a large commercial business.—The fruit shipped under the last series was grown and packed by a corporation owning several hundred acres of groves and packing its own fruit. When the present investigation of the Bureau of Plant Industry was undertaken in 1905, the fruit from this house sometimes arrived in market showing from 5 to 30 per cent of decay. The handling of the fruit was done with the average care used in preparing the fruit for market at that time. An investigation showed that 20 to 25 per cent of the oranges were cut with the clippers or were stem punctured, and that the packing house, which was equipped with overhead sizers, contributed to the further injury of the fruit. In 1906 and in 1907 the fruit was picked with care. The labor in the groves is paid by the day. It is under the management of a competent foreman. As a rule the orange as cut from the tree has a long stem, and a second cut removes the stem close to the fruit. The pickers average from 40 to 50 boxes a day, and the clipper cutting and stem puncturing have been reduced to from 1 to 3 per cent. The loading and the hauling of the boxes to the packing house are done with care. Gravel is kept out of the boxes and they are not filled full enough to bruise the oranges on the top when the boxes are stacked. The packing house is handled by a skillful foreman. The oranges are not brushed. The machinery is of the simplest kind and is run at comparatively low speed. The packing and the loading of the cars are done with care. The packers average from 50 to 60 boxes a day. The fruit has been shipped under ventilation until about two months after most of the shipments from southern California have begun to be forwarded under ice.

From the business standpoint this fruit took high rank in the market as soon as careful handling methods were adopted in 1906, and it has held it ever since. In addition to a good pack, it has commanded the confidence of buyers on account of arriving in sound condition day after day. The excess in net return has been many times greater than the extra cost of careful handling. The extra cost of handling the fruit carefully has probably not amounted to 10 cents a box.

What has been accomplished here can be duplicated, so far as the sound arrival of the fruit is concerned, by any other shipper in California who will preserve the natural keeping quality of the fruit by handling it carefully in the grove and packing house rather than attempting to handle the shipments at the lowest possible cost under conditions that make the fruit susceptible to decay.

THE SHIPMENTS UNDER ICE.

The shipments under ice in 1907 began in March and extended to the last of May. They were made from different parts of the citrus

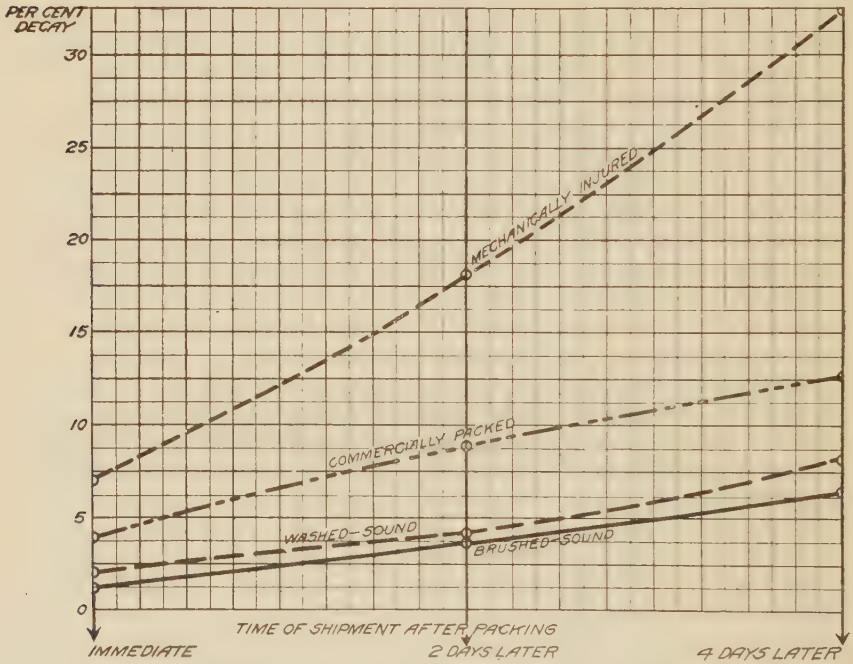


FIG. 11.—Diagram illustrating the percentage of decay in oranges handled rather roughly, shipped under ice, February to April, 1907.

belt. There were two series of shipments under ice. The first was from a group of houses in which the fruit was handled in the groves and packing houses rather roughly. It included apparently sound brushed and washed fruit, commercially packed fruit, and mechanically injured fruit. The second series was from a group of houses in which the fruit was handled in the groves and packing houses with more than average care. It included apparently sound brushed fruit, commercially packed fruit, and mechanically injured fruit.

The result of the shipments under the first series, shown also in figure 11, is brought out in Table V:

TABLE V.—*Percentage of decay in oranges handled rather roughly and shipped under ice, February to April, 1907.*

Treatment or condition of fruit.	Decay following immediate shipment and approximate delay of 2 days and 4 days.			
	(None.)	(2 days.)	(4 days.)	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Brushed fruit, apparently sound	1.2	3.7	6.4	3.8
Washed fruit, apparently sound	2.0	4.2	8.1	4.8
Commercially packed fruit	3.9	8.9	12.6	8.5
Mechanically injured fruit	7.0	18.1	32.4	19.2
Average	3.5	8.7	14.9	

Two important factors similar to those developed in the shipments under ventilation are brought out by these shipments: (1) The decay is least in the fruit that is handled the least, i. e., the apparently sound brushed fruit, and greatest in the fruit that is mechanically injured; (2) the decay increases as the time between packing and shipping increases. The delay in shipping the fruit causes the least injury to the soundest fruit and develops the greatest injury in the mechanically injured oranges.

The result of the shipments from the houses in which the fruit was handled with care is brought out in the following table:

TABLE VI.—*Percentage of decay in oranges handled carefully and shipped under ice, March to May, 1907.*

Treatment or condition of fruit.	Decay following immediate shipment and approximate delay of 2 days and 4 days.			
	(None.)	(2 days.)	(4 days.)	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Brushed fruit, apparently sound	1.0	1.8	2.6	1.8
Commercially packed fruit	1.0	2.6	4.6	2.7
Mechanically injured fruit	7.9	9.0	14.7	10.5
Average	3.3	4.5	7.3	

As in the other series under ice, the least decay developed in the sound brushed fruit and the greatest amount occurred in the mechanically injured oranges. The decay is proportional to the length of time that elapses between packing and shipping. The decay in all of the shipments in the second series is less than that in the fruit that was handled more roughly, on account of the sounder condition of the fruit.

A practical illustration of careful handling methods.—There are included in the last series shipments from a grower with extensive groves, whose fruit early in the season of 1907 arrived in New York in bad condition. Some of the carloads developed as much as 25 per cent of decay. Both the shipper and the receiver thought the decay was due to excessive tenderness of the fruit brought on by over-

fertilizing or to other methods followed in handling the groves. An investigation of this case showed that about 20 per cent of the fruit was mechanically injured in handling. The pickers were paid by the box. It was not considered essential to ship the fruit as soon as it was picked. The packing-house machinery was not well adapted to the careful handling of the fruit, and in the packing house the labor was done with no great care.

The grower decided to change his method of handling the crop. Two or three foremen were tried in the groves before a satisfactory man was found to handle the picking gang; the labor was paid by the day, the picking was done with care, clipper cutting and other injuries were reduced to an average of about 5 per cent, the packing-house equipment was remodeled and simplified, the fruit was not brushed, and it was delivered by hand from the picking boxes to a wide belt that led to the sorting table. The packing-house operations were conducted with more care than formerly. The result of these changes is one of the most striking that has come under the observation of the representatives of the Bureau of Plant Industry.

The decay in the commercial shipments disappeared as soon as the old methods were changed and did not reappear throughout the season. From the business standpoint the brands from this grower, which up to this time had been handled with caution by the New York buyers, commanded confidence and sold at prices not often surpassed by other brands of fruit. The fruit from this house handled in the experimental shipments developed the following average decay: Apparently sound unbrushed fruit, 1.2 per cent; commercially packed fruit from the same bins, 4.1 per cent; mechanically injured fruit from the same bins, 14 per cent. This grower has recently stated that by insisting rigidly on the careful handling of the oranges the net increased receipts averaged from 50 cents to $1.50 a box after the change in methods was adopted.

An illustration of better handling methods.—There were also included in the shipments under ice oranges from an association that in 1905 had the reputation of producing fruit of the poorest carrying quality, though excellent in other respects. An inquiry in several markets showed that the receivers always expected excessive decay in the brands of this fruit. Many of the growers believed that the decay was due to mysterious local climatic and soil conditions. An investigation of the case in 1906 showed that the growers had depended on the *Scutellista cyanea* Matsch to hold the black scale in check and little fumigation or spraying had been done in the section for three or four years. The groves were badly infested with scale. Probably 90 per cent of the fruit had to be washed. The packing-

house management exercised little control over the picking of the fruit. On the whole, it was carelessly picked, much of it showing from 25 to 30 per cent of injury. The handling of the fruit in other respects was done with average care. The packing house was of the type shown in Plate III, figure 2. The fruit that was washed passed through more than a thousand feet of machinery of different kinds before it was packed. The fruit often remained in the house a week or more before it was shipped.

As the conditions in this association were typical of many others, both packing-house experiments and shipping experiments were carried on during 1906 and 1907. In 1906 the fruit in the packing-house experiments developed the following amount of decay: Apparently sound unbrushed fruit, 1.9 per cent; apparently sound dry-brushed fruit, 4.2 per cent; apparently sound fruit run through the washers and all other machinery, 19 per cent; mechanically injured fruit, 23 per cent.

The growers were convinced from these experiments that the fruit was not inherently poor in keeping quality. There was a general fumigation of the groves in the section in the autumn of 1906, and not more than 50 per cent of the fruit was washed in 1907. The overhead machinery was eliminated, the equipment considerably simplified and changed, the picking was done with more care in 1907, part of it by a picking crew under the control of the packing house, and the fruit was shipped out more quickly whenever the car shortage did not delay the shipments. In 1907 the average decay in the shipping experiments was as follows: Apparently sound brushed fruit, 1.8 per cent; apparently sound washed fruit, 2.6 per cent; commercially packed fruit, 4.8 per cent; mechanically injured fruit, 26.9 per cent.

This association has not yet reached the limit of practical improvement, but the reputation of its brands of fruit has already been elevated to a higher class, as the fruit has continued to arrive in the markets in better condition than formerly.

THE SHIPMENTS OF PRECOOLED FRUIT.

The shipments of precooled oranges in 1907 were begun in March and extended into May. They included apparently sound brushed and washed fruit, commercially packed fruit, and mechanically injured fruit, placed in cold storage at different lengths of time after packing and allowed to remain there until the fruit reached a temperature of 35° to 40° F., when it was shipped in refrigerator cars cooled by icing before the oranges were loaded.

The result of the shipments from a group of houses in which the fruit is handled roughly in the groves and packing houses is shown in the table following and also in figure 12:

TABLE VII.—*Percentage of decay in precooled oranges, March to May, 1907.*

Treatment or condition of fruit.	Decay following immediate cooling after packing and a delay of 2 days and 4 days.			
	(None.)	(2 days.)	(4 days.)	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Brushed fruit, apparently sound	0.1	2.3	3.4	1.9
Washed fruit, apparently sound	0.8	2.3	5.5	2.9
Commercially packed fruit	2.2	6.2	9.1	5.8
Mechanically injured fruit	3.0	9.2	13.9	8.7
Average	1.5	5.0	8.0	.....

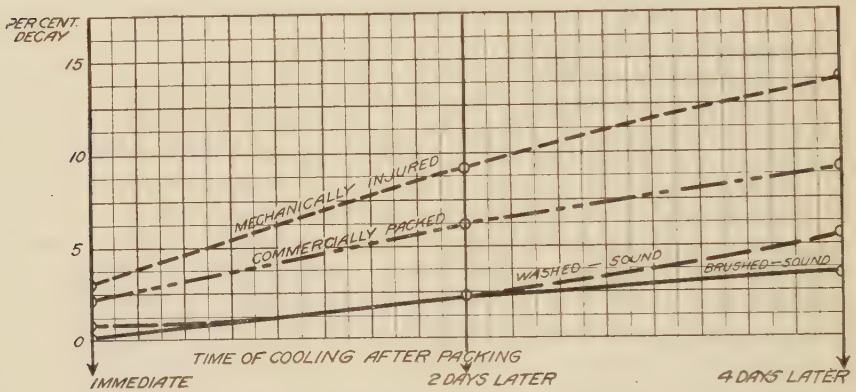


FIG. 12.—Diagram illustrating the percentage of decay in oranges cooled before shipping, March to May, 1907.

It will be seen from the table and from figure 12 that the apparently sound brushed fruit decayed least and that there was a progressive increase in the decay through the washed, the commercially packed, and the mechanically injured fruit. This increase in respect to the different types of fruit is similar to that occurring in the shipments under both ventilation and ice. The precooled shipments also bear out the principle of the shipments under ventilation and ice in that the least decay developed in the oranges that were cooled quickly after packing, and considerable decay developed in the fruit in which there was a delay in cooling after it was packed. It appears to be as essential to cool the fruit quickly if it is to be cooled before shipment as it is to ship it promptly after packing, under ventilation or ice. If the decay has an opportunity to develop for several days after the fruit is packed, it can not be eliminated by cooling the fruit to a lower temperature later on.

A COMPARISON OF THE DECAY FOUND IN CONNECTION WITH THE DIFFERENT METHODS OF SHIPMENT.

By comparing the data under the different methods of shipment it will be seen that the apparently sound brushed fruit arrived under all conditions of shipment with the least decay; that the apparently sound washed fruit, which is more susceptible to decay on account of the washing and additional handling to which it is subjected, decayed more; that the commercially packed fruit, which contains more or less injured fruit, decayed still more, and that the greatest amount of decay developed in the mechanically injured fruit. Sound fruit to start with, therefore, is the foundation for sound fruit in market under all methods of shipment.

It is equally clear that it is essential to ship the fruit promptly after packing or to cool it quickly if it is to be cooled before shipment. A delay of two days in shipping under ventilation or ice or in the cooling of the fruit resulted in an increase in decay, while a delay of four days developed a still greater amount, the increase being least in the apparently sound dry-brushed fruit and greatest in the mechanically injured fruit. It is better to leave the fruit on the trees until it can be shipped than to pick it and leave it in the packing house several days before shipment unless the weather is cold enough to retard the development of decay.

As to the amount of decay under the different methods of shipment, the least decay developed in the precooled fruit, provided the shipments from the houses that handle the fruit roughly, as shown in figures 10, 11, and 12, are compared. On the other hand, there was less decay in the carefully handled commercial shipments under ventilation, discussed on page 44, than in any other series, notwithstanding the fact that the shipments extended through a greater length of time than those that were iced or precooled. This was due to the sounder condition of this fruit as a result of the careful handling methods used in its preparation for market. It will be seen also that the decay in the fruit shipped under ice from the group of houses that handle oranges carefully, discussed on page 47, is less than the decay in the roughly handled fruit cooled before shipment, discussed on page 46 and shown in figure 11.

The comparative data bring out clearly that if the fruit is uninjured when it leaves California it is likely to arrive in the East in comparatively sound condition, and that under adverse conditions, such as a delay in shipping the fruit, there is less decay in apparently sound fruit than in oranges that have been injured by handling. These data show clearly that it is detrimental to the shipping quality to delay the shipment of the fruit after it is picked and packed, and,

finally, that fruit which is susceptible to decay develops the least trouble when shipped under the precooling method.

THE OBJECT OF COOLING FRUIT BEFORE SHIPMENT.

The principal object of cooling fruit before shipment is to quickly retard the ripening processes and the development of decay and to equalize the temperature in the car during the trip. In ordinary iced shipments the fruit is loaded in a car in a warm condition. It requires several days after the fruit is loaded before the temperature of the fruit is reduced to a degree of cold that retards the ripening and the decay. The ripening springs forward with unusual rapidity as soon as a fruit is picked, and as the air of the car is moist from the transpiration of the fruit the conditions are favorable to the rapid development of decay. In a refrigerator car the fruit is cooled by a slow gravity circulation of air from the ice bunkers. The temperature of the air as it leaves the bunkers may fall as low as 34° F. It is warmed by contact with the fruit and grows warmer as it ascends and reenters the ice bunkers of the car. The temperature in the top of the car is several degrees warmer than in the bottom during the first part of the trip, as shown in figure 20, but this difference gradually grows less as the fruit becomes cold.

These are fundamental difficulties in the present methods of handling perishable fruits. They limit the distribution of fruit to the area over which the top tiers of packages can be safely shipped, thereby preventing the development of the most distant domestic and foreign markets. They make it necessary to harvest the summer fruits prematurely to provide against the ripening that takes place in transit, thereby placing large quantities of insipid, flavorless peaches, plums, and other fruits before the consumers.

THE REFRIGERATION OF CITRUS FRUITS IN TRANSIT.

All of the considerations previously mentioned do not apply to the shipment of oranges under the ordinary methods of refrigeration. The ripening processes in citrus fruits proceed so slowly and are of such a nature that it is not necessary to ice the cars to retard the ripening even with ripe fruit in hot weather. The citrus fruits are iced primarily to retard the development of decay and secondarily to retain the fresh appearance of the fruit on arrival in market by preventing undue evaporation from the skin during the trip. A carload of oranges under refrigeration cools down slowly, as each orange is partly insulated in the paper wrapper. The loose ends of the wrappers make a layer of paper between the rows of oranges, and the fruit is packed so firmly that this prevents a free circulation of cold air

around each orange. The cooling is done by conduction of heat from orange to orange and to the air surrounding the packages. In warm weather a car of fruit often covers from one-fourth to one-third of the trip across the continent before the temperature of the oranges drops to 50° F., as shown in figures 18 and 19. The fruit, therefore, may decay during the first part of the trip if it has been handled in such a way as to make it susceptible to decay, especially if it is not shipped promptly after picking and packing. If it is shipped promptly it does not decay excessively except in hot weather, as will be seen by reference to figure 11. The icing of the fruit retards the development of decay temporarily. It transfers the decay from the shipper to the receiver. It does not affect the shipping quality, except the general appearance, or the keeping quality of sound oranges, but it is a means of overcoming for the time being the bad effect of handling the fruit improperly in the groves and packing houses.

THE COOLING OF ORANGES BEFORE TRANSPORTATION.

The cooling of the orange before shipment insures less decay in transit in poorly handled fruit, as the fruit is started in a cold rather than a warm condition. The fruit arrives in sounder condition, but the oranges that might have decayed in transit under ventilation or ordinary icing decay after the fruit is removed to a warm temperature unless it passes quickly into consumption, as shown in figures 14 and 15. Icing or precooling used primarily to overcome the effect of improper methods of handling in the groves and packing houses should be severely condemned, as it is a means of deceiving the purchaser who buys fruit that is apparently sound only to find the decay developing as soon as the fruit is removed to a warm temperature.

The use of icing or of precooling as a means of overcoming losses that the grower and shipper can not prevent in the ordinary course of business is commendable and is essential in the handling of most of the orange crop in California in warm weather.

The precooling of citrus fruits is worthy of consideration from other points of view. It appears to be possible to save ice in transit by loading the fruit in a cold rather than a hot condition, and it seems to make it possible to increase the freight-carrying capacity of a car if the fruit is properly cooled, without increasing the probability of decay. Theoretically the heat withdrawn in reducing a carload of 384 boxes of oranges from 70° to 40° F. is equivalent to the melting of about 2.6 tons of ice. The rest of the ice used in transit is consumed in protecting the fruit against the heat that comes in through the car and in cooling the car itself. The cars,

however, have to be iced before loading when cold fruit is shipped in them, a practice that is not followed under ordinary icing. The saving of ice in precooled fruit when the cars are reiced as often as they are under ordinary icing is slight and does not appear to be of practical importance. The saving comes, however, from the fact that it does not seem necessary to reice precooled fruit during the first part of the trip as often as it is done in ordinary icing. In the shipments in which the temperatures in the cars have been under observation during the transcontinental trip, the temperature of the fruit cooled to 35° and 40° F. has not begun to rise, even in hot weather, until a third or a half of the transcontinental trip has been covered, while in cooler weather the cars have covered the entire trip to New York without a detrimental rise in temperature, often arriving with at least a ton of ice in the bunkers. Under regular icing the cars are reiced six or eight times during a transcontinental trip. Representative records of precooled cars shipped from California with initial icing only are shown in figures 24 and 25.

It is not intended to draw conclusions from the data at hand as to the effect of precooling as a means of saving ice, but rather to present a limited amount of data to show that this phase of the subject is worthy of careful consideration on the part of shippers and transportation companies.

The second point worthy of consideration is the possible increase in the freight-carrying capacity of a car when loaded with fruit that has been cooled properly for shipment. Under the present method of shipment, the minimum freight weight of a carload of perishable produce is established not by the actual carrying capacity of the car, but by the height to which it is safe to load the car without excessive decay in the top tier or tiers of fruit and by the spacing between the packages that it is necessary to leave for a free circulation of air.

In the experimental shipments of the Bureau of Plant Industry, a number of 40-foot cars have been forwarded with 549 instead of 384 boxes, the latter number being a standard load under ordinary icing. The increase has been accomplished by loading the cars 7 rows of boxes wide, leaving all of the space next to the walls of the car, and 3 tiers high, the upper tier being laid on the side, instead of 6 rows wide and 2 tiers high, as loaded under ordinary icing. The standard method of loading is shown in figure 3. The method of loading with 549 boxes is shown in figure 13. Under the latter method of loading the fruit may arrive in New York in hot weather with a difference in temperature of 5 to 10 degrees between the top and bottom tiers of fruit, as shown in figure 23, but as the temperature of the fruit is low when it is loaded, it appears to be safe to ship oranges in this

manner in cool weather. In hot weather the cars can be loaded 2 tiers high and 7 rows wide, making 448 boxes. In the first case the capacity of the car is increased 165 boxes, or 11,880 pounds, and in the second case 64 boxes, or 4,608 pounds. In a train of 30 cars the load is increased 356,400 pounds in the first case or 138,240 pounds in the second without adding dead weight to be hauled in the form of extra cars.

This phase of the subject seems worthy of careful consideration on the part of shippers and transportation companies, especially in a time of car shortage.

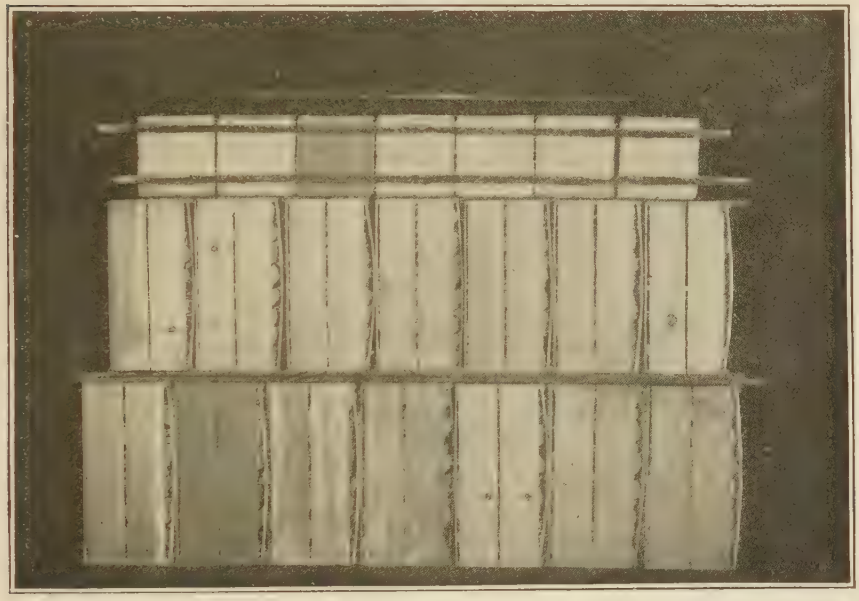


FIG. 13.—Boxes of oranges packed in accordance with the method used in loading a car with 549 boxes.

HISTORICAL DATA ON THE PRECOOLING OF ORANGES.

The first precooling of oranges was done at the plant of the Los Angeles Ice and Cold Storage Company, Los Angeles, Cal., in the spring of 1905. At that time several carloads of fruit were cooled to 35° to 40° F. in the warehouse for the Bureau of Plant Industry, and, through the cooperation of this company, about 10 loaded cars were cooled by forcing cold air from a coil room in the cold-storage house through ducts which led to the car and back to the coil room. The cold air could be forced in either direction through the cars. A general view of the plant used in 1905 is shown in Plate IX, figure 1.

The same line of work was continued in 1906 by the Bureau of Plant Industry, the fruit being cooled in the cold-storage warehouse.

A 3-ton ice machine was installed by a commercial company in a packing house at Arlington, Cal., in the spring of 1906, from which cold air was forced through a loaded car and back over a series of ammonia coils, and so on continuously around the circuit. The plant was built on a so-called intermittent vacuum principle, the object being to reduce the atmospheric pressure in the car frequently by a fan, thereby drawing the warm air out of the packages, to be replaced by the cold air when the cold current was again turned on. The capacity of this plant was too small for the purpose of either a practical or experimental demonstration of its value.

In the spring of 1907 the Bureau of Plant Industry had erected, under the direction of Mr. S. J. Dennis, expert in refrigeration, an experimental plant in cooperation with the Los Angeles Ice and Cold Storage Company, for the purpose of making accurate tests of the

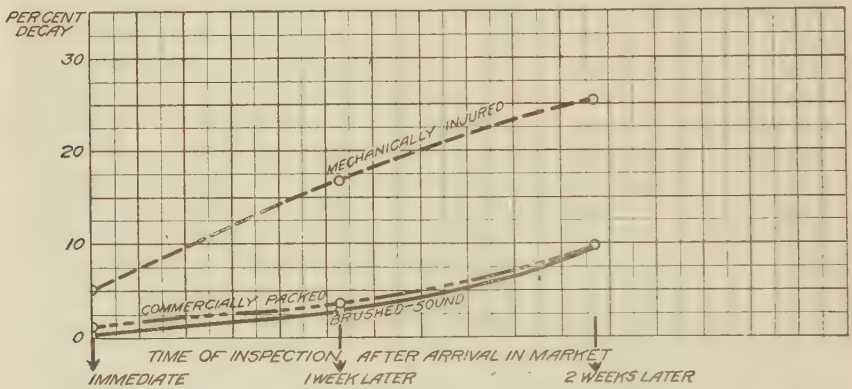


FIG. 14.—Diagram illustrating the percentage of decay upon arrival in market and for two weeks thereafter of precooled oranges handled carefully, 1907.

cooling of oranges in cars by forcing cold air through the cars. This plant consisted of two 30-inch-square insulated ducts leading from an ammonia coil room capable of supplying from 16 to 20 tons of refrigeration in 24 hours. With a motor and fan the cold air was forced in either direction through the car and back to the coil room. The temperature of the air was varied from 20° F. when first entering the car to higher temperatures. It was forced through the car at different velocities and in volume varying from 4,500 to 6,000 cubic feet a minute. This plant is shown in Plate IX, figure 2. It is hoped to present a report on this plant from the engineering point of view and a discussion of the cold storage of oranges in a future bulletin of the Bureau of Plant Industry on "The Cooling of Fruit for Shipment."

In addition to the work at the plant at Los Angeles, Cal., extensive shipping experiments were conducted by the Bureau of Plant Industry in 1907 with fruit cooled in cold-storage plants in different parts of the State. A few cars were cooled also at the 3-ton plant at Arlington, Cal., by different parties, and about 300 cars of fruit were cooled commercially in different cold-storage warehouses, the fruit having been stored primarily on account of a shortage in cars.

During the summer of 1907 an experimental precooling plant was erected by interests connected with the Santa Fe Railroad at San

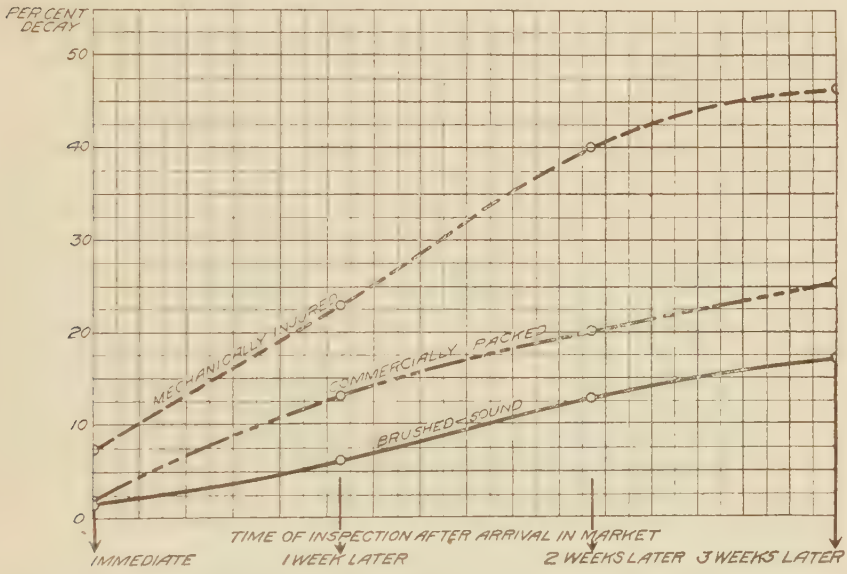


FIG. 15.—Diagram illustrating the percentage of decay upon arrival in market and for three weeks thereafter of oranges handled roughly, shipped under ice, 1907.

Bernardino, Cal., and another plant at Roseville, Cal., by interests connected with the Southern Pacific Company.

THE KEEPING QUALITY OF ORANGES AFTER ARRIVAL IN MARKET.

During the season of 1907 data have been secured on the keeping quality of oranges after arrival in market, the fruit having been prepared for shipment in different ways in California. The shipments included apparently sound brushed and washed fruit, commercially packed fruit, and mechanically injured fruit. Shipments were forwarded under ventilation, under ice, and after precooling, but not under conditions that make a comparison of the three methods feasible.

On arrival in New York the fruit was held for different lengths of time in a storeroom of a wholesale fruit merchant, and the decay was determined at the end of each succeeding week in storage. Shipments of this type arrived during April, May, and June.

One series of tests included the regular commercial shipments of a large corporation whose fruit is handled in the groves and packing houses with extreme care. The fruit is the same as that represented by the results discussed on page 45. All of it was forwarded

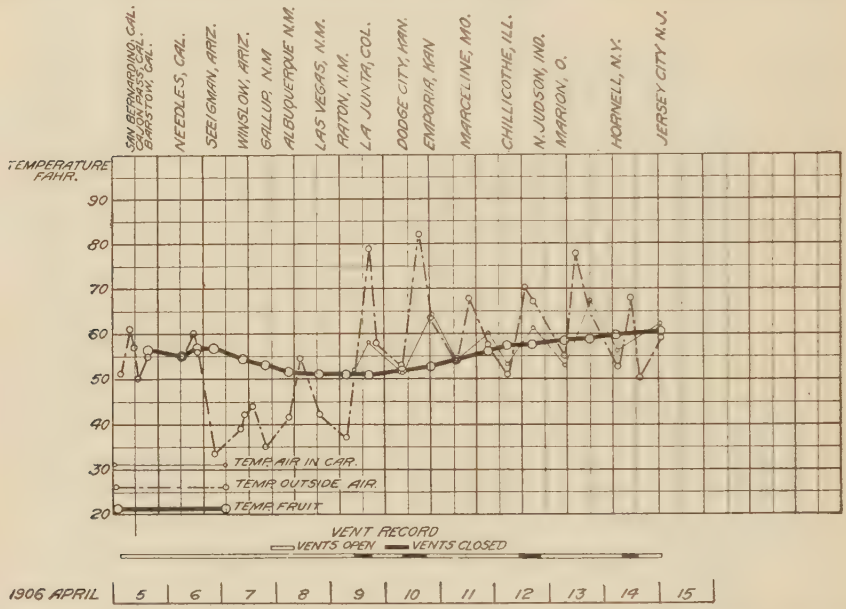


FIG. 16.—Diagram showing the temperature record of a carload of oranges shipped under regulated ventilation, April, 1906.

under ventilation. The decay developed at different lengths of time after arrival in New York is shown in the following table:

TABLE VIII.—*Percentage of decay in carefully handled oranges, shipped under ventilation, after arrival in New York, 1907.*

Character of oranges shipped.	Time of inspection.			
	On arrival.	After 1 week.	After 2 weeks.	After 3 weeks.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Commercially handled fruit	2.4	5.0	9.1	11.1

There was also forwarded from this house in June, after precooling, some carefully selected fruit, commercially packed fruit, and mechanically injured fruit. The decay in the different lots at

different lengths of time after arrival in New York is shown in the following table, and also in figure 14 (p. 56):

TABLE IX.—*Percentage of decay in precooled oranges handled carefully, after arrival in New York, 1907.*

Character of oranges shipped.	Time of inspection.		
	On arrival.	After 1 week.	After 2 weeks.
	Per cent.	*Per cent.*	*Per cent.*
Apparently sound fruit	0.4	2.8	9.7
Commercially handled fruit	1.2	3.6	9.7
Mechanically injured fruit	5.2	16.7	25.4

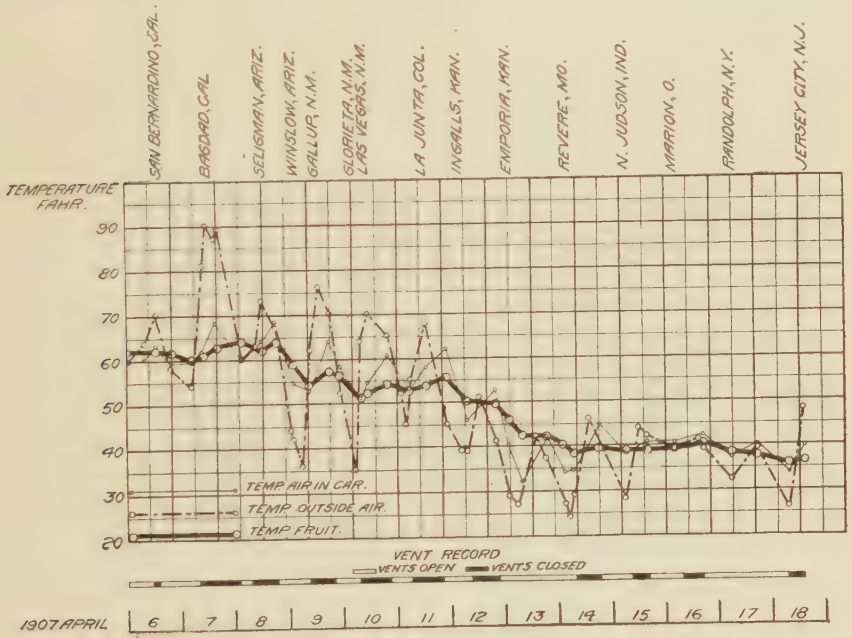


FIG. 17.—Diagram showing the temperature record of a carload of oranges shipped under regulated ventilation, April, 1907.

These data are comparable with the decay under ventilation so far as the commercially packed fruit is concerned. There was a little less decay in the precooled than in the ventilated fruit on arrival, and the development after arrival was slightly less. The difference shown is so slight as to be of no practical value except to indicate that precooled fruit that is reasonably sound is not more likely to decay after arrival in market than equally sound ventilated fruit. The increase was slightly less in the apparently sound fruit and greatest in the injured fruit.

The following table shows the amount of decay in fruit from houses where the oranges handled were picked and packed rather roughly, the fruit arriving during May and June under ice. The data are shown also in figure 15 (p. 57).

TABLE X.—*Percentage of decay in oranges handled roughly, shipped under ice, after arrival in New York, 1907.*

Character of oranges shipped.	Time of inspection.			
	On arrival.	After 1 week.	After 2 weeks.	After 3 weeks.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Apparently sound fruit	1.4	6.1	12.7	17.0
Commercially packed fruit	1.9	13.0	20.7	25.3
Mechanically injured fruit	7.4	22.9	39.9	46.1

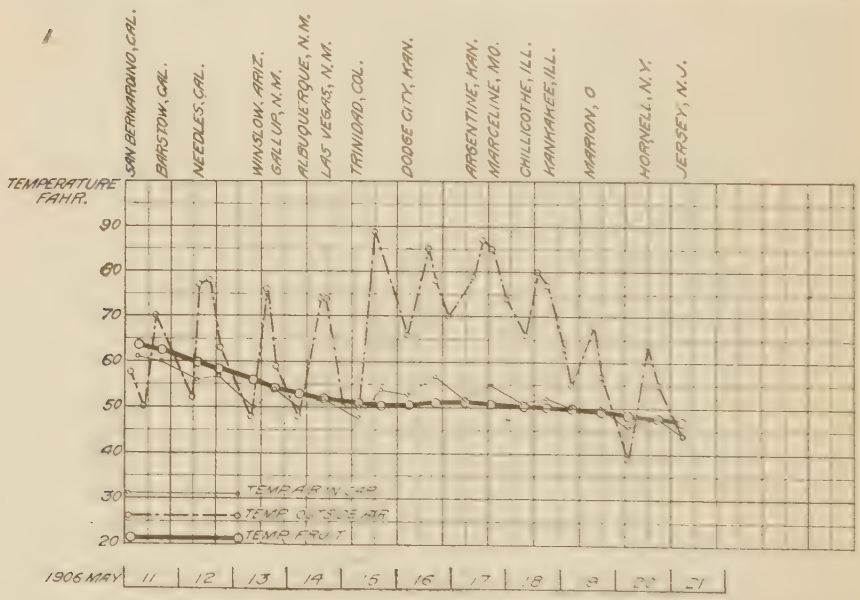


FIG. 18.—Diagram showing the temperature record of a carload of oranges shipped under regular icing, May, 1906.

This table shows the least development of decay in the apparently sound oranges and the greatest development in the mechanically injured fruit. The increase in decay in the commercially packed fruit, which contains more or less injured fruit, is greater than the decay in the sound fruit from which the oranges showing visible mechanical injuries have been eliminated.

The data on the keeping quality of the fruit in New York, taken as a whole, show clearly that sound fruit to start with is the basis for good keeping quality after arrival in market, as well as the basis

for soundness on arrival: that carefully handled sound fruit keeps as well when shipped under precooling as ventilated fruit, but that unsound fruit having the decay retarded during shipment either by precooling or by icing decays badly when exposed to a warm atmosphere. The general impression that iced fruit decays more quickly than ventilated fruit when exposed to warm air is usually true so far as oranges that are mechanically injured are concerned, as the injured fruit is more likely to develop decay in transit under ventilation, but it is not well founded when applied to sound fruit.

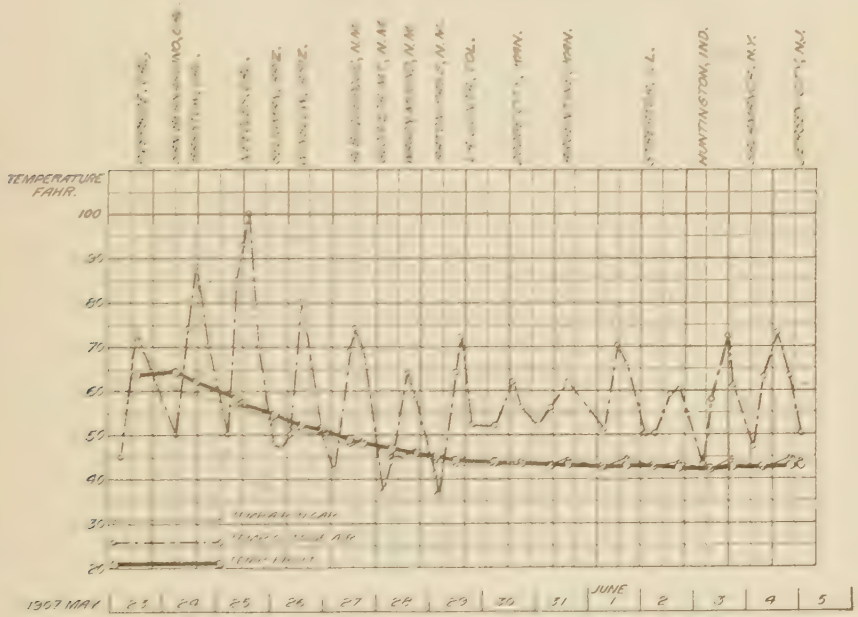


FIG. 19.—Diagram showing the average temperature record of two carloads of oranges shipped under regular icing, May, 1907.

THE INVESTIGATION OF THE TEMPERATURE OF ORANGES WHILE IN TRANSIT.

During the spring of 1906 and that of 1907 an investigation was made of the changes that occur in the temperature of the fruit, the air in the car, and the outside air during the movement of cars of fruit across the continent under ventilation, icing, and with fruit cooled before shipment and forwarded under several conditions of icing. The records were taken by Mr. G. W. Hosford and Mr. H. M. White, who made several trans-continental trips with train loads of oranges, reading the thermometers several times a day by entering the cars at the icing stations and other stopping points.

This investigation was made possible through the cooperation of the railroads in allowing the icing in transit, the reading of the thermometers, and other matters connected with the investigation to be done by, or under the direction of, the representatives of the Bureau of Plant Industry. The records appearing in this discussion were made in cars forwarded over the Santa Fe route.

From three to six thermometers were placed in each car, one to determine the temperature of the air just above the boxes of fruit, the others to determine the temperature of the fruit itself. These latter were inserted in oranges in the packed boxes. With the exception of a few cases noted, the fruit temperatures were taken in the upper half of boxes in the upper tier midway between the door and the end of the car, one thermometer being placed in an orange next to the outside of the box, and another in an orange in the inside or center of the box. For this purpose special long mercurial ther-

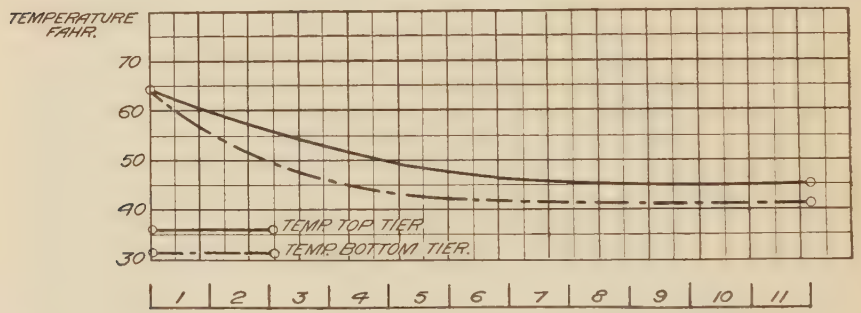


FIG. 20.—Diagram showing the temperature change of the oranges in the top and bottom tiers of boxes in a car shipped under regular icing.

mometers were used which could be read without being removed from the orange. The fruit temperature shown in the following diagrams is the average of the inside and outside fruit temperatures. In some cars a thermometer was placed in the lower half of a box in the lower tier in front of the door. All of the records were made in standard 40-foot refrigerator cars loaded with 384 boxes, except as noted. The diagrams that follow cover two representative records under each method of shipment.

TEMPERATURE RECORDS IN VENTILATED CARS.

The accompanying chart, figure 16, shows the temperature record of a car shipped in April, 1906. The record of the temperature of the air of the car was not begun until the train reached the vicinity of Raton, N. Mex. This car was forwarded under regulated ventilation; that is, the ventilators, or ice plugs, in each end of the car were sup-

posed to be closed whenever the outside air was warmer than the fruit and were opened when the outside air was colder. The regulation in this respect differs from the standard ventilation in practice, which usually provides, so far as the temperature is concerned, that the ventilators shall be closed whenever the outside temperature falls below 32° F., but does not provide against the rise in temperature in the car when the outside air is above the temperature of the fruit. The regulation of the ventilators in this car was not entirely accurate, as shown in the vent record at the bottom of the chart. The fruit temperature is an average of the temperature in the inside of a box

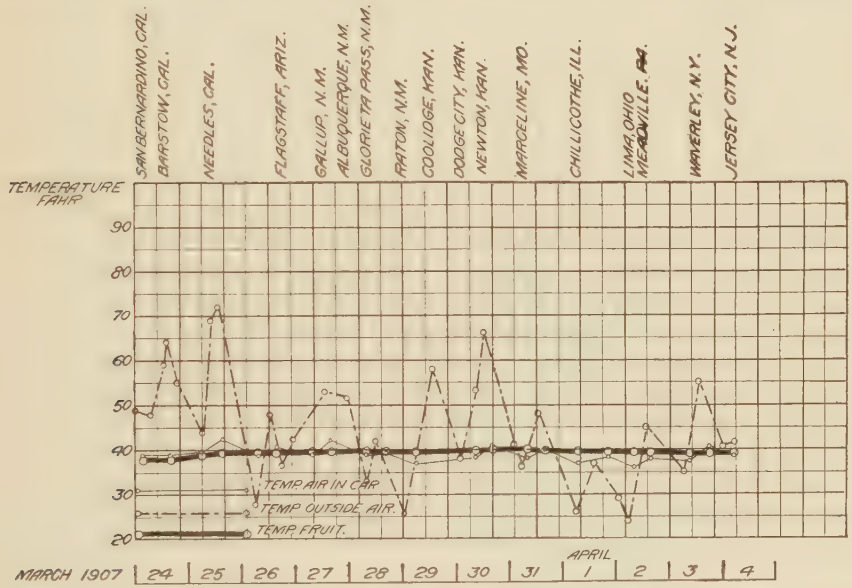


FIG. 21.—Diagram showing the temperature record of a standard carload of 384 boxes of oranges, precooled and shipped under regular icing, March and April, 1907.

in the top tier at the end of the car and the temperature in the fruit in a similar position in the center of the car.

It will be seen that the temperature of the air of the car lags behind the temperature of the outside air, while the lag in the fruit temperature is much greater than that of the air of the car. The fruit temperature changes slowly even when extreme differences occur outside.

The chart shown as figure 17, page 59, presents the temperature record of a car of oranges shipped under regulated ventilation in April, 1907, with somewhat different weather conditions from those occurring on the former trip.

The results of the experiments with this car demonstrate the fact that the temperature of the fruit changes much more slowly than the temperature of the outside air. It is worth noting that several times during the trip the temperature of the outside air fell below 32° F. and at one time dropped to 24° F. Notwithstanding the fact that the vents were open at the time, the temperature of the fruit, while falling steadily, did not reach a point where there was danger of freezing. Two days of this comparatively low temperature, April 13 and 14, 1907, only reduced the fruit from 50° to 38° F.

The substance of these records shows that the temperature of a carload of oranges under ventilation changes slowly in comparison

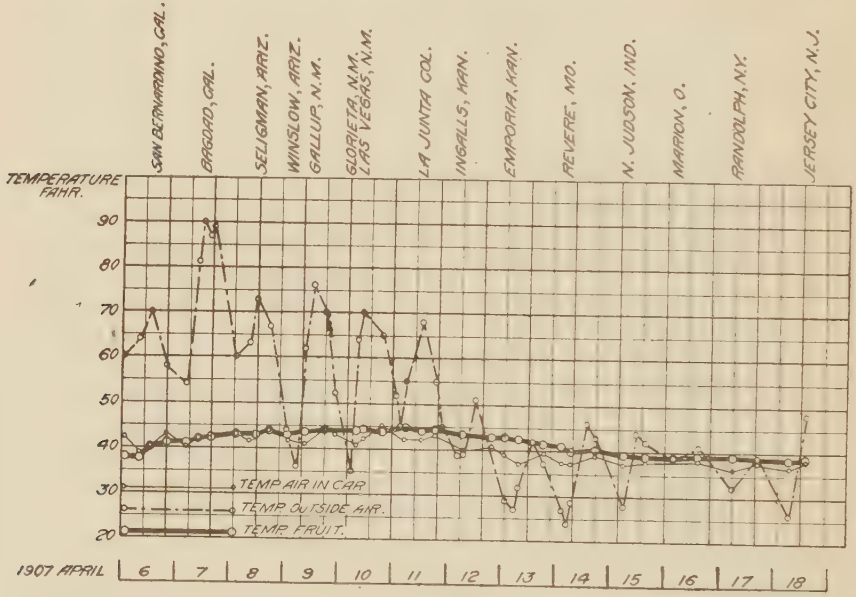


FIG. 22.—Diagram showing the temperature record of a carload consisting of 549 boxes of oranges, precooled and shipped under regular icing, April, 1907.

with the temperature of the outside air; that the temperature outside may often fall to the freezing point or below without injury to the fruit, provided the fruit temperature is somewhat above that point at the time; that the danger of freezing depends on the persistence of and the degree of the low temperature without or the nearness of the fruit to it when the car enters a freezing temperature; and that the temperature of the fruit in transit would be more uniform if protection was made against warm temperatures as well as against cold in the handling of the ventilators. This suggests the need of an organized messenger service for the regulation of ventilated fruit cars, the ventilation to protect the fruit against both excessive cold and heat.

TEMPERATURE RECORDS IN ICED CARS.

The chart shown as figure 18, page 60, shows the record of a carload of oranges shipped under ice in May, 1906. The fruit started at 63° F., which is comparatively cool, and the outside air was also comparatively cool until the train reached western Kansas, after which it averaged considerably higher, except at the end of the trip. The temperature of the fruit was 63° F. in starting and reached 50° F. on the fifth day, but did not fall much lower, while the outside temperature remained high.

The record shown in figure 19 (p. 61) represents the average temperature of two cars shipped in the same train under ice in May, 1907. Each car showed practically the same temperature throughout the trip. The temperature of the fruit is the average of five different temperatures in each car. Two of them were taken in the usual

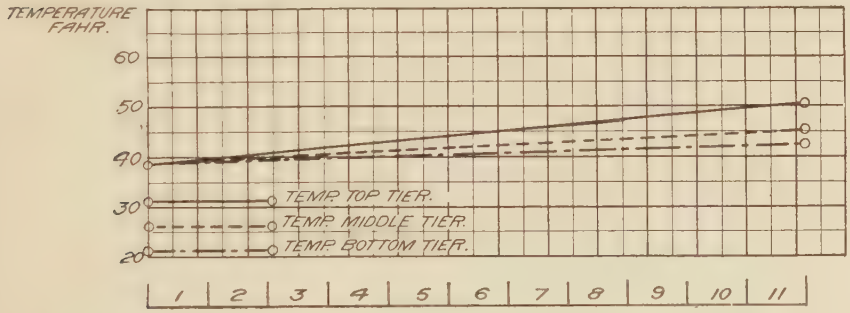


FIG. 23.—Diagram showing the temperature changes in the fruit in the bottom, middle, and top tiers in a carload of 549 boxes of oranges, precooled and shipped under initial icing only.

place, halfway between the door and end of the car, two were taken in the top tier in the middle of the car and represent the average temperature of the inside and outside fruit, and the fifth in the center of the box in the lower half of the lower tier in front of the door. The fruit started at 64° F., reached 50° F. on the fourth day, and arrived in Jersey City at 43° F.

The chart shown as figure 20, page 62, shows the average cooling of the oranges in the top and bottom tiers of boxes in the cars shipped under ice in 1907. The temperature was taken in the upper half of the boxes in the top tier and the lower half of the boxes in the bottom tier. The bottom tier cooled faster than the top for several days, the maximum difference reaching 7 to 8 degrees on the third and fourth days of the trip. Gradually the extreme difference between the tiers disappeared, the temperatures of the two tiers from the seventh day remaining about 4 degrees apart.

The records show, in substance, that under icing the fruit is not reduced to a low temperature until a considerable part of the transcontinental trip has been covered, and that the fall in temperature in the top tier lags behind the bottom tier throughout the trip. These records indicate the reason why the fruit sometimes decays excessively when shipped under ice and why the top tiers of fruit, especially in cars of deciduous fruit, reach the market in an overripe and decaying condition. Many oranges leave California at a temperature of 80° F. or higher. The decay starts during the early part of the trip under the icing method, before the fruit is cooled.

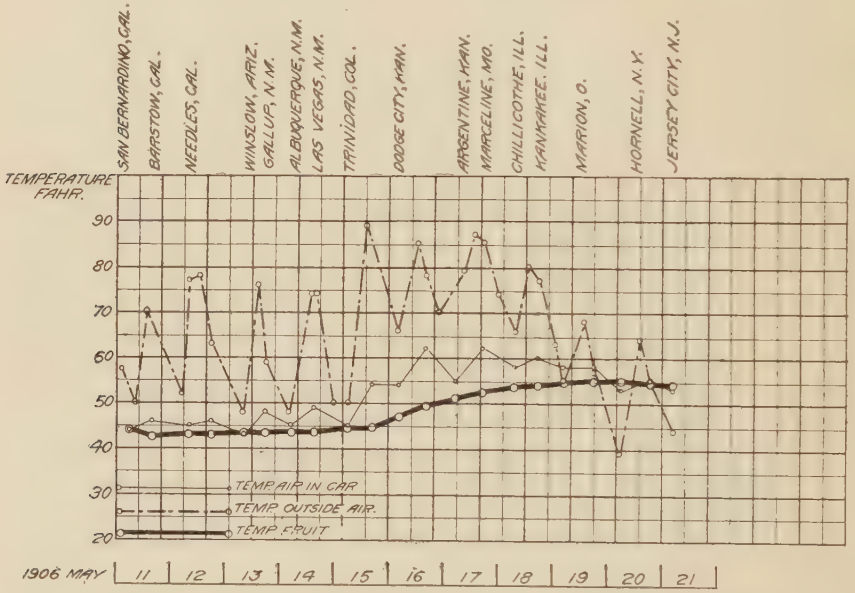


FIG. 24.—Diagram showing the temperature record of a carload of oranges, precooled and shipped under initial icing only, May, 1906.

TEMPERATURE RECORDS OF FRUIT COOLED BEFORE LOADING AND ICED REGULARLY IN TRANSIT.

The chart shown as figure 21 (p. 63) is a record of the temperature of a carload of oranges of 384 boxes placed in cold storage before loading and which left California in March, 1907, at a temperature of 38° F. The car was iced before the fruit was loaded and was reiced in transit at the regular icing stations. The temperature of the fruit remained practically constant throughout the trip, the air of the car changing slightly with the outside air.

The accompanying chart, figure 22 (p. 64), is a record of the temperature of a carload of 549 boxes of oranges placed in cold storage before loading and which left California in April, 1907, at a temperature of 38° F. The car was iced before the fruit was loaded and was

reiced regularly in transit. All of the thermometers in this car were placed near the door. The fruit temperature is an average of the fruit next to the outside of a box in the third or top tier and the fruit in the center of the lower half of a box in the bottom tier. The temperature of the fruit rose to 45° F. during the first half of the trip and probably would have risen higher if the outside temperature had not been colder during the latter half of the trip.

The accompanying chart, figure 23 (p. 65), illustrates the average temperature of the fruit in the different tiers of a 3-tier car loaded with 549 boxes. The fruit was loaded into the car at a temperature of 38° F. Upon arrival in Jersey City it was found that the temperature

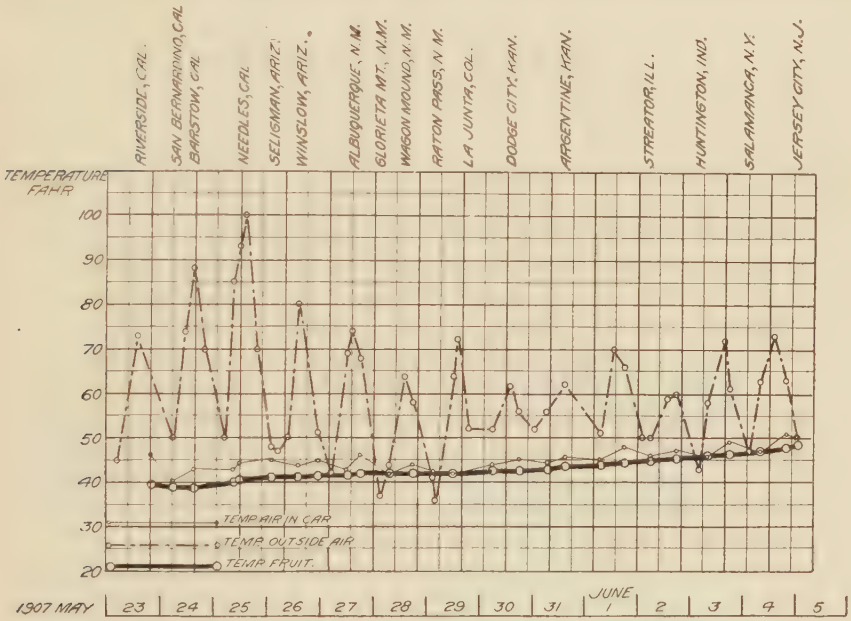


FIG. 25.—Diagram showing the temperature record of a carload of oranges, precooled and shipped under initial icing only, May and June, 1907.

on the top tier was 51°, the middle tier 48°, and the bottom tier 43° F. This is the largest difference that has been found in any of the 3-tier precooled cars under observation. The record is the result of reading the temperature of the fruit at the beginning and end of the trip and is not a continuous record from day to day.

TEMPERATURE RECORDS OF FRUIT COOLED BEFORE LOADING AND ICED IN CALIFORNIA ONLY.

The chart shown as figure 24 is a record of a carload of oranges placed in cold storage before loading and which left California in May, 1906, at a temperature of 42° F. The car was iced before loading and was reiced at San Bernardino before leaving California. It

was not reiced during the rest of the trip. It arrived in Jersey City with about 700 pounds of ice in the two bunkers. During the first half of the trip the weather was reasonably warm, but the temperature of the fruit remained fairly constant. During the latter half, through Kansas and as far as Illinois, the outside temperature was higher. The temperature of the car then began to rise, the temperature of the fruit rising also from 45° to 55° F., but lagging considerably behind, with a tendency to recede during the cooler weather at the end of the trip. In this connection the record of the car under ice shown in figure 18, made in the same train, should be noted. In this car the fruit started at a temperature of 63° and did not drop

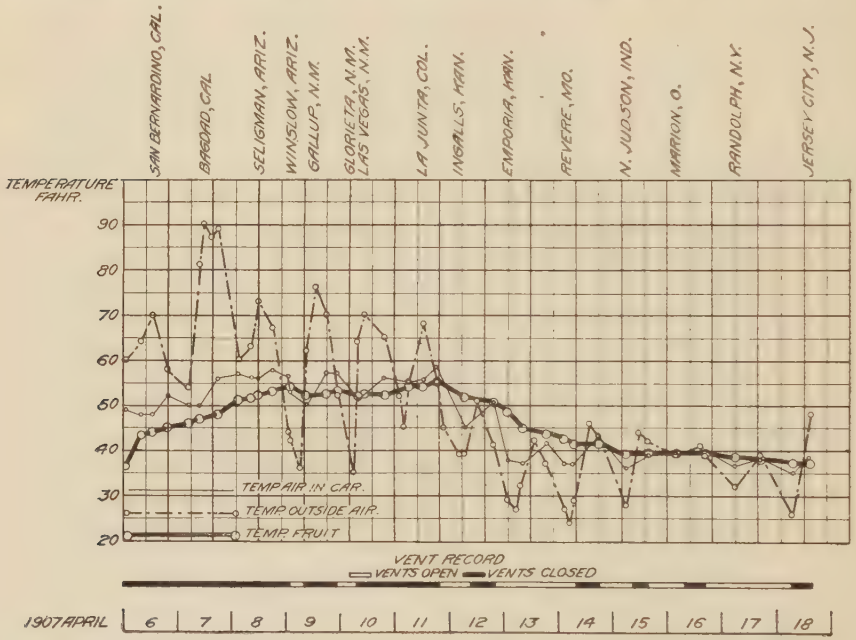


FIG. 26.—Diagram showing the temperature record of a carload of oranges, precooled and shipped without icing under regulated ventilation, April, 1907.

below 50° F. during the warm weather. In the fruit precooled and iced in California only it started at 42° and rose during the latter half of the trip as high as 55° F. The condition of temperature in the precooled car is preferable so far as the decay of the fruit is concerned.

The chart shown as figure 25 is a record of a carload of oranges of 416 boxes placed in cold storage before loading and which left California in May, 1907, at a temperature of 39° F. This car was iced before loading and was reiced at San Bernardino before leaving California, but not during the rest of the trip. The car was loaded 7 rows of boxes wide on the bottom tier and 6 rows wide on the top

tier. It arrived in Jersey City with 3,000 pounds of ice in the two bunkers. The temperature of the fruit rose gradually from 39° to 48° F. In this connection the record of the iced car shown in figure 19, which was in the same train, should be noted. The lower temperature during the latter half of the trip reduced the temperature of the fruit to a lower degree than the fruit in the iced car shown in figure 18, and at the same time it prevented as great a rise in the cold fruit as occurred in the car shown in figure 24. It also saved the ice as compared with the car shown in figure 24.

The chart shown as figure 26 shows the record of a carload of oranges placed in cold storage which left California in April, 1907, at a temperature of 37° F. The car was not iced either before or after loading. It was forwarded with the ice plugs inserted. The temperature outside was warm and the temperature of the fruit rose rapidly. After the train reached Winslow, Ariz., the temperature of the air at night began to fall below the temperature of the fruit, and from that point on the car was run under regulated ventilation. The record indicates that it is not safe, so far as the temperature of the fruit is concerned, to load precooled fruit in warm weather in a hot car and to forward it without ice.

SUMMARY OF PRECOOLING RECORDS.

The substance of the records under precooling demonstrates that the temperature remains fairly constant in fruit that has been cooled and is forwarded in a car iced before loading and iced regularly in transit; that the temperature of fruit cooled to about 40° F., forwarded in a car iced before loading, and reiced at San Bernardino, Cal., only, remains fairly constant for at least half of the transcontinental trip, when the temperature may begin to rise if the weather is warm; that it may be safe to ship oranges cooled to about 40° F. to points in the western half of the United States with California icing only, provided the time in transit is normal; that the fruit may be shipped across the continent in reasonably cool weather when handled under the preceding conditions; that the need of reicing in transit would probably have to be governed by the quantity of ice remaining in the bunkers at any point and not by a predetermined fixed rule, and that it is not safe to load cold fruit in a warm car and forward it without icing.

SUMMARY.

The citrus-fruit crop of California amounts to nearly 30,000 cars annually, of which the orange comprises from 85 to 90 per cent. The fruit is grown under intensive culture, and the handling, shipping, and marketing of the crop have resulted in the development of complex and highly specialized business practices.

The losses from decay in the orange during transportation formerly amounted to $750,000 to $1,500,000 annually. The decay is caused by a blue-mold fungus which enters the orange through mechanical abrasions in the skin. The most common forms of mechanical injury are those caused by the clippers in cutting the fruit from the tree, stem punctures, and scratches and bruises produced in the packing houses. Most of these injuries are invisible to the inexperienced eye. There has been a wide variation in the amount of injury in the fruit of different pickers, growers, and packing houses, the variation commonly running from 1 to 50 per cent. A good deal of the trouble has been related to methods of business which place a premium on the amount rather than the quality of the work done by the picker, the grower, or the packing house.

By holding in many packing houses in California fruit that has been picked at different periods of the season, in different sections of the citrus belt, and that has been handled in different ways, it has been shown that the fruit that is handled the least develops the least decay, while the fruit that shows the greatest amount of injury develops the most decay. From the standpoint of the packing house, the least decay develops in sound unbrushed fruit. Brushing increases it, washing increases it still more, and any treatment that cuts or tears the skin is followed by the greatest amount of decay.

There appears to be little difference in the amount of decay in oranges grown in different sections that have been handled in a similar manner, or in oranges picked from the same grove with equal care at different periods of the season, at least from January to May.

The "curing" of the orange for a few days before packing wilts the skin and in the early part of the season makes it pliable to handle. The curing is probably not harmful to uninjured fruit, but under the conditions of commercial handling in California the blue mold begins to develop in the injured oranges during the curing period, but does not develop far enough to be seen by the graders except in fruit that has been injured severely.

If the fruit is packed promptly after picking and is shipped at once in a cool temperature the decay may not develop in transit. The most progressive shippers now pack the fruit promptly after picking.

It is unnecessary to brush so large a proportion of the oranges as has been customary in the past, and the washing can be avoided by treating the groves properly for scale. The packing houses all through the citrus belt are being modified in the direction of more simple machinery.

The shipping experiments of the Bureau of Plant Industry during the last three years have included 297 shipments of fruit to New

York. The shipments have included oranges handled in different ways before packing. The fruit has been shipped at different lengths of time after packing, and it has been forwarded under ventilation, icing, and precooling followed by different conditions of icing.

From the standpoint of the handling of the fruit the least decay has developed under all methods of shipment in the sound, carefully handled oranges, and the greatest amount has developed in those that were mechanically injured. From the standpoint of the promptness of shipment after packing the least decay has developed in the oranges shipped immediately after packing, and the decay has increased in proportion as the time between packing and shipment has lengthened. From the standpoint of the method of shipment the least decay developed in the precooled fruit that was loaded in the cars in cold condition.

The cooling of the fruit to a temperature of about 40° F. before shipment appears to save ice in transit, as the cars do not require reicing as often as they do when forwarded under regular icing. It appears also to increase the freight-carrying capacity of a car by making it possible to load the boxes more closely than is safe under regular icing. From the standpoint of decay, precooling the fruit is not essential, as the decay can be avoided by handling the fruit carefully. Precooling retards decay temporarily, but does not remove the cause. It should supplement rather than take the place of careful handling.

In the market holding tests the fruit that has not been mechanically injured keeps the longest, while the greatest loss occurs in oranges that have been thus injured.

The temperature of the fruit changes slowly in transit. In ventilated cars there may be extreme changes in the outside air, and if the extremes do not persist long the changes in the temperature of the fruit are relatively slow. In iced cars the temperature falls relatively fast during the first few days, but a train may cover one-third of the trip across the continent before the temperature of the fruit reaches 50° F. The decay develops rapidly during the early part of the trip, while the fruit is warm. In a car in which the fruit is cooled to 40° F. or lower before shipment the temperature remains nearly constant if the car is reiced regularly in transit. In cool weather it remains fairly constant without additional icing after the car leaves California. In warm weather the reicing during the first half of the trip can be avoided, but the car may need reicing during the latter half of the trip.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. *Frontispiece.* Washington Navel oranges, showing blue-mold decay. The upper figure shows the stem cut short, with an injury in the fruit made by the clippers. The decay started at this injury. The lower figure shows an orange with a long stem and a puncture made by such a stem. The decay is developing around the injury. (Fruit considerably reduced in size.)

PLATE II. Washington Navel orange trees. Fig. 1.—One of the Washington Navel orange trees sent to California by the Department of Agriculture in 1873. Fig. 2.—A Washington Navel orange tree three years after planting.

PLATE III. California orange groves and a packing house. Fig. 1.—A typical view of bearing orange groves. The foreground shows contour planting to facilitate irrigation. Fig. 2.—Interior view of an orange packing house in southern California, with an old-style overhead sizing machine and gravity chutes leading to the bins. This type of house contains too much complicated machinery to insure careful handling of the fruit.

PLATE IV. Orange brushing machines. Fig. 1.—A common type of brushing machine with a hopper. Fig. 2.—A belt-carrying device placed over the brush to deliver the fruit from the hopper to the elevator. This device can be removed when it is desired to brush the fruit.

PLATE V. Machinery in use in an orange packing house in southern California. Fig. 1.—An automatic weighing machine in operation. Fig. 2.—One type of sizing machine in operation. The narrow carrying belts on either side are used to return to the graders poor fruit found in the bins.

PLATE VI. An interior view of a desirable type of orange packing house. This is a type of house without overhead or complicated machinery. The grading belt in the background is shown in detail in text figure 2. The drop from the grading belt to the sizers is necessary to allow room for the weighing machines. (From a photograph furnished by the manager of the packing house.)

PLATE VII. The washing of citrus fruits. Fig. 1.—A lemon washing machine in operation. The fruit is emptied into the tank of water at the right of the picture. It is then cleaned between revolving brushes in the circular tank and delivered on the canvas table at the left, where it is graded according to color. Similar machines are used in washing oranges. Fig. 2.—Washed oranges on drying racks.

PLATE VIII. Valencia oranges. The upper specimen was taken from a grove that had been thoroughly fumigated for the black scale. The lower specimen is from a grove that had not been fumigated for the black scale. The sooty-mold fungus on the upper part of the fruit grows in the honeydew exuded by the scale. Such fruit has to be washed. (Fruit considerably reduced in size.)

PLATE IX. The cooling of oranges in cars before shipment. Fig. 1.—The experimental plant used in 1905. Fig. 2.—The experimental plant erected and used in 1907.

Bul. 113, Bureau of Plant Industry, U. S. Dept. of Agriculture.

FIG. 1.—A TREE SENT TO CALIFORNIA BY THE DEPARTMENT OF AGRICULTURE IN 1873.

FIG. 2.—A TREE THREE YEARS AFTER PLANTING.

WASHINGTON NAVEL ORANGE TREES.

FIG. 1.—A TYPICAL VIEW OF BEARING ORANGE GROVES.

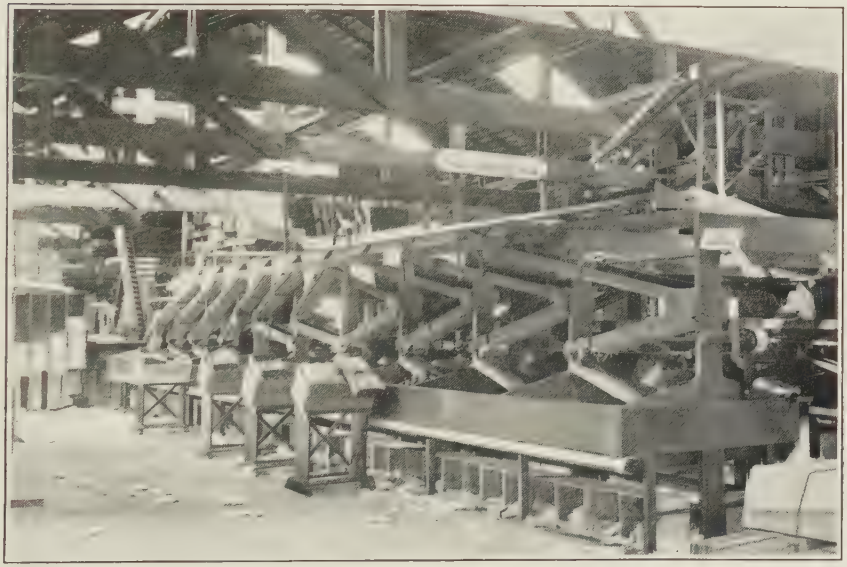


FIG. 2.—INTERIOR VIEW OF AN ORANGE PACKING HOUSE WITH AN OVERHEAD SIZING MACHINE.

CALIFORNIA ORANGE GROVES AND A PACKING HOUSE.

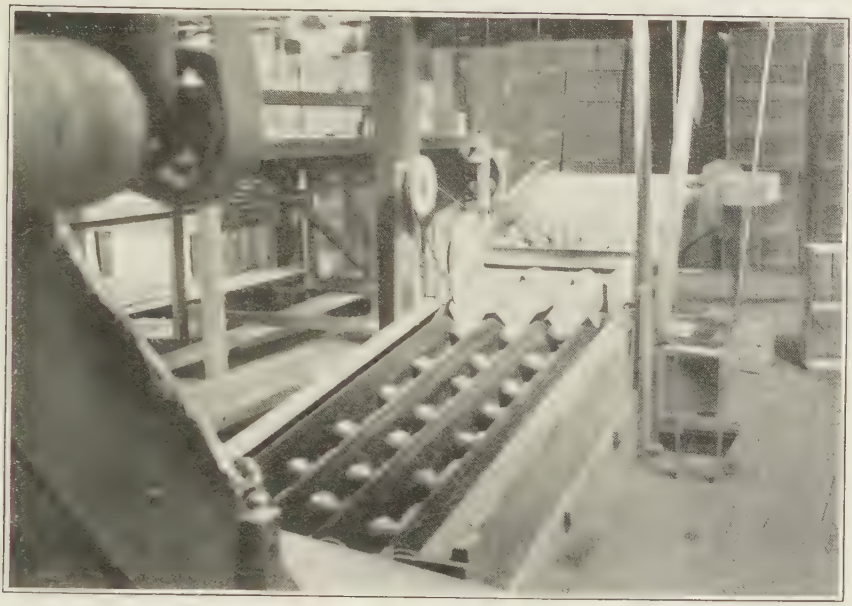


FIG. 1. A COMMON TYPE OF BRUSHING MACHINE, WITH A HOPPER.

FIG. 2.—A BELT-CARRYING DEVICE OVER A BRUSHING MACHINE.

ORANGE BRUSHING MACHINES.

FIG. 1.—AN AUTOMATIC WEIGHING MACHINE

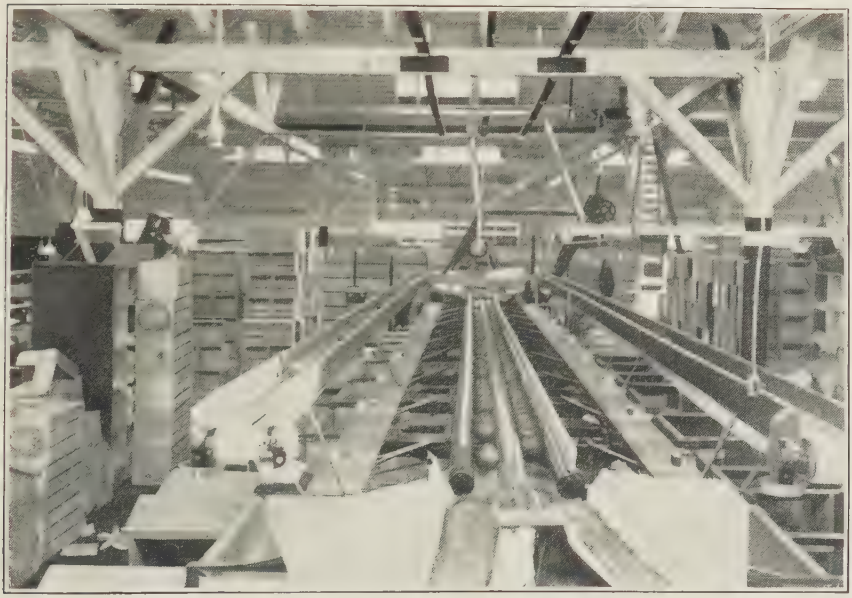
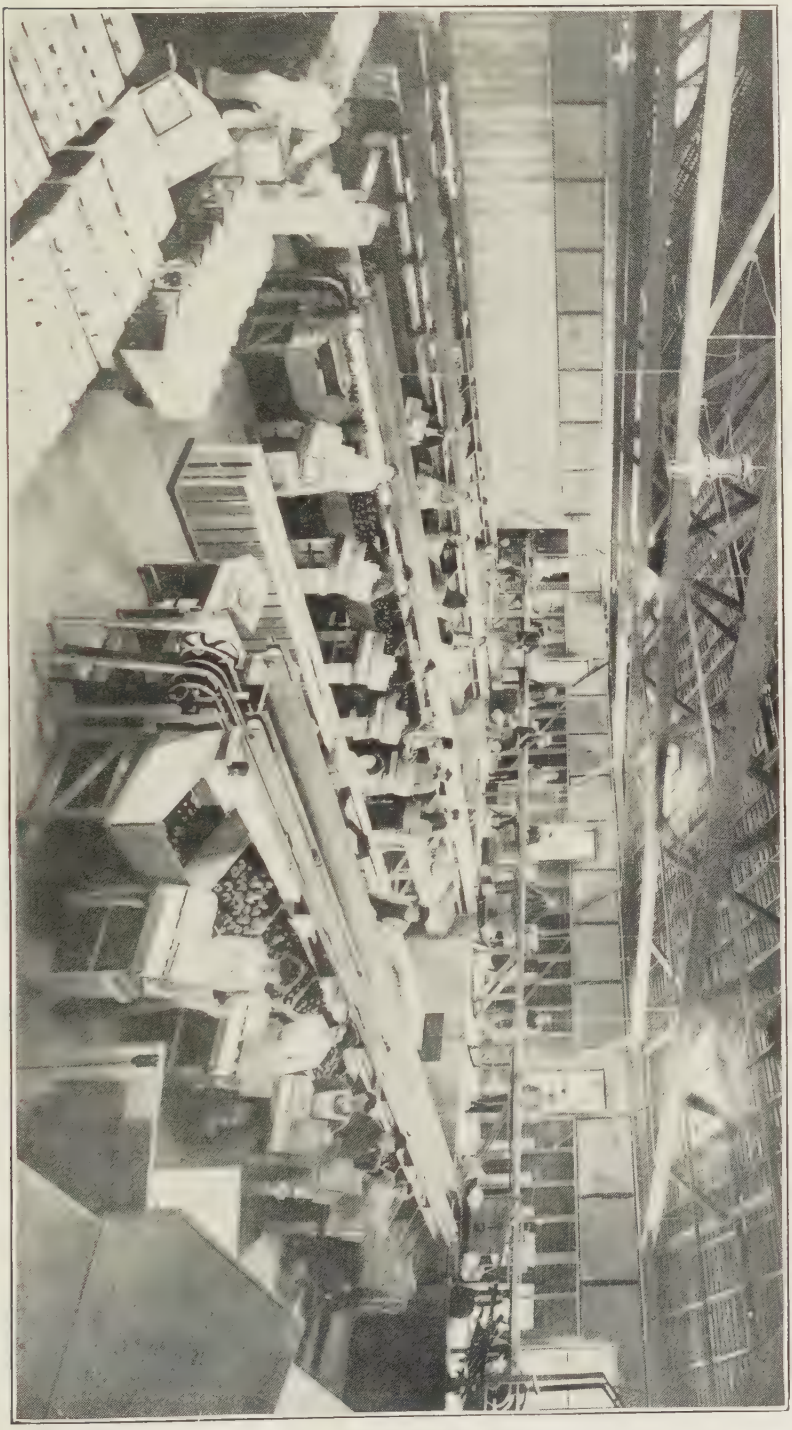


FIG. 2.—A TYPE OF SIZING MACHINE.

ORANGE PACKING-HOUSE MACHINERY.



AN INTERIOR VIEW OF A DESIRABLE TYPE OF ORANGE PACKING HOUSE.

FIG. 1.—A LEMON WASHING MACHINE IN OPERATION.

FIG. 2.—WASHED ORANGES ON DRYING RACKS.

THE WASHING OF CITRUS FRUITS.

E. J. Schutt

VALENCIA ORANGES.

Lower specimen affected with sooty-mold fungus.

(Specimens considerably reduced in size)

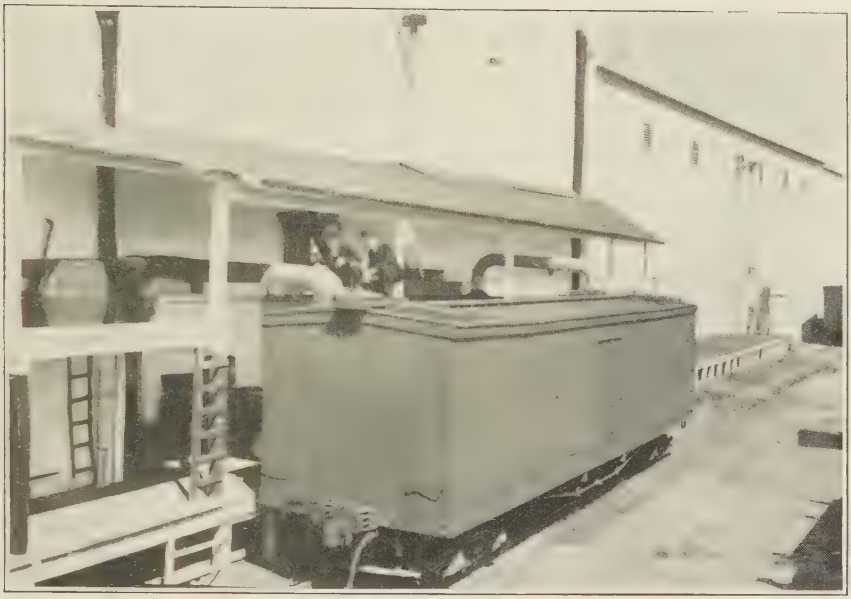


FIG. 1.—THE EXPERIMENTAL PLANT USED IN 1905.

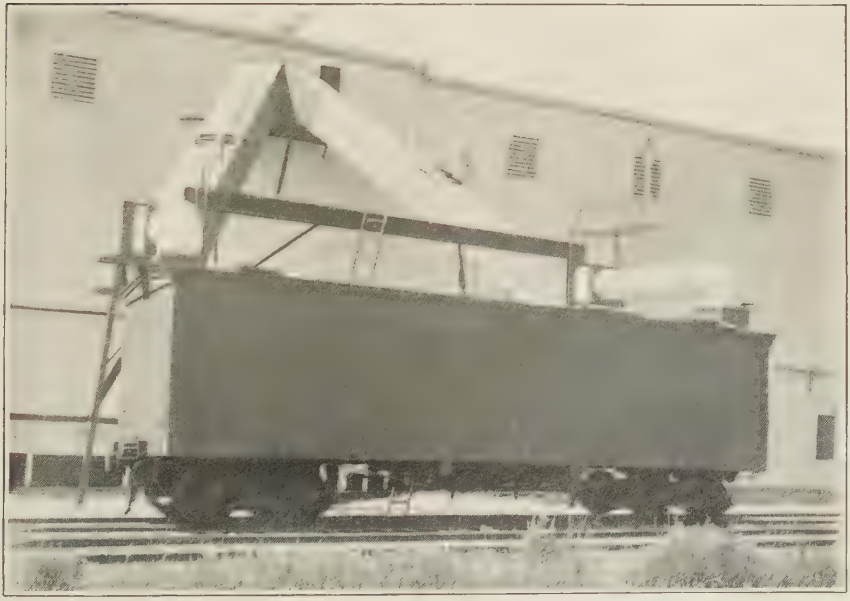


FIG. 2.—THE EXPERIMENTAL PLANT USED IN 1907.

THE COOLING OF ORANGES IN CARS BEFORE SHIPMENT.

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